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GEOLOGICAL SOCIETY

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SECOND SERIES.

VOLUME VI.

PART THE FIRST.

Quod si cui mortalium cordi et curæ sit, non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant.

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Aug. 28. Report of the Eighth Meeting of the British Association for the Advancement of Science, held at Newcastle, August 1838. vol. 7.	The British Association.
Philosophical Transactions of the Royal Society of London for 1839, part 1. 4to. London.	The Royal Society.
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Reports of the Geological Survey of New York for 1838. 8vo. 1839.	Capt. J. W. Pringle, F.G S.
June 2. The Zoology of the Voyage of H.M. Ship Beagle, under the command of Capt. Fitzroy, during the years 1832 to 1836, edited and superintended by Charles Darwin, Esq., Sec. G.S. Fishes, by the Rev. Leonard Jenyns, M.A., no. 2 of part 4. 4to. London, 1840.	Charles Darwin, Esq., Sec. G.S.
June 5. Mémoire sur diverses couches de Terrain nouvellement découvertes aux environs de Paris, entre la Craie et l'Argile Plastique, par Charles D'Orbigny. 12mo. Paris.	The Author.
June 8. Proceedings of the Royal Irish Academy, No. 23. 8vo.	The Royal Irish Academy.
June 10. A Dictionary of Geology and Mineralogy, by William Humble, M.D. 8vo. London, 1840.	The Author.
The London and Edinburgh Philosophical Magazine and Journal of Science, conducted by Sir David Brewster, K.C.H., LL.D., F.R.S. L. & E.,	

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The Repertory of Patent Inventions, and other discoveries and improvements in Arts, Manufactures, and Agriculture, July 1839 to June 1840. 8vo. London.	The Proprietor.
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The Athenæum Journal of English and Foreign Literature, July 1839 to June 1840. 4to. London.	The Editor.
Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, par MM. les Secrétaires Perpetuels; July 1839 to June 1840. 4to. Paris.	The Academy of Sciences of Paris.

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1840.	
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I.—*On the Geology of the Western Part of Asia Minor.*

By WILLIAM JOHN HAMILTON, Esq., Sec. G.S., and
HUGH EDWIN STRICKLAND, Esq., F.G.S.

(Drawn up by the Authors, from Memoirs read November 2, 1836, March 13, 1839, and April 29, 1840.)

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PREFACE.

In the spring of 1836 we proceeded from the south coast of the sea of Marmora to Brusa*, and thence up the previously unexplored course of the river Rhyndacus† to its sources, whence we crossed to the Plain of Hushak, and descended the valley of the Hermus to Smyrna. In the following year, one of the authors (Mr. Hamilton) followed a track nearly parallel to the above, but from thirty to fifty miles further westward, or from Cyzicus to the river Macestus, and across the Demirji range to Koola (lat. 38° 31′, long. 28° 44′). These two excursions, and a third previously made (by Mr. Strickland) into the valleys of the Mæander and Cayster, together with journeys in the valley of the Mæander, and a voyage from Smyrna to Rhodes (by Mr. Hamilton), have supplied the materials for the following sketch of the geology of a portion of Asia Minor‡.

Our principal object has been to describe correctly the phænomena which we

* See Map, Pl. I.

† We have in many instances, in the following memoir, used the ancient names of districts, mountain-chains and rivers, in preference to their modern Turkish denominations; the former being more generally understood as well as more exact in their application than the latter. The names of towns and villages on the contrary are chiefly Turkish. All the places mentioned in this memoir will be found on the new map of Asia Minor to accompany Mr. Hamilton's forthcoming journal. See also the Map, Pl. I.

‡ The memoirs, from which the paper is compiled, although referring to nearly the same line of country, were drawn up by their respective authors in a very different manner; when therefore the question of their publication came before the Council, it was considered desirable that the several papers should be embodied in one memoir, to avoid unnecessary repetition, and that the materials should be so arranged as to give at one glance a more enlarged view of the general structure of the country.

observed ; but as geological facts are dry and uninteresting without arrangement, we have ventured on such a classification as the rocks of Asia Minor appeared naturally to admit. We are, nevertheless, well aware how imperfect such a first attempt at generalization must be in a country which had been only partially explored, and concerning the geology of which, we could obtain very little satisfactory information from external sources. We wish, therefore, the general views here advanced to be considered as provisional, and open to correction ; our only source of confidence in them being derived from the general simplicity of materials and uniformity of arrangement which mark the rocks of Asia Minor, and which render the task of classification much easier than in many other districts of equal extent. It remains, however, a question of some doubt, how far the relative antiquity of the metamorphic rocks can safely be depended upon ; and whether they are not in some instances really secondary deposits, which have been acted upon by the volcanic and igneous influences, which have operated so abundantly throughout the peninsula of Asia Minor.

Physical Structure of Western Asia Minor.

The western part of Asia Minor is thickly beset with mountains, some of which form chains of considerable extent, but others are more isolated and indefinite in form. These mountains are often alpine in their character, and present many points of interest to the general observer. They rise for the greater part abruptly from horizontal plains, the smooth and verdant surface of which is strikingly contrasted with the rugged outlines of the surrounding mountains. It will be seen hereafter, that this abrupt transition from mountain to plain is the result of peculiar geological conditions. (See *posteà*, p. 13.)

On the great scale, the prevailing direction of these alpine chains is nearly east and west. This *latitudinal strike* is exhibited in no less than six parallel ranges.

1. The chain of Olympus. This mountain-tract commences with Mount Ida (lat. 39°40′), whence a range of high land extends eastward to the Mysian Olympus, the snowy summit of which is about 7000 feet above the sea. Beyond this point, the same chain re-appears under the ancient name of the Bithynian Olympus, and ranges eastward as far as the Halys. The chain sends numerous streams from its northern slope into the sea of Marmora and the Euxine ; and the Macestus, Rhyndacus and Sangarius, conduct the drainage of its southern slopes through transverse gorges, the two former into the sea of Marmora after passing through the lake Apollonia, and the last directly into the Euxine.

2. The chain of Temnus or Demirji (lat. 39° 5′). This range is furcated at its western end, inclosing the valley of the Caicus. These branches unite to the

N.E. of Thyatira, and form the chain of Demirji, which constitutes the watershed between the Hermus on the south and the Macestus and Rhyndacus on the north, and terminates in Morad Dagh, near Kutahiyah.

3. The chain of Tmolus commences with Mount Tartali near Smyrna, and forms a narrow and lofty ridge, which, after dividing the valleys of the Hermus and Cayster, passes to the southward of Koola and terminates to the S.E. of Takmak.

4. The range of Messogis (lat. 38°), which commences at Ephesus, and divides the fertile plains of the Cayster and the Mæander. At its northern end it unites with the range of Tmolus, and thus completely separates the Caystrian Plain from the surrounding country. It then extends eastward to the south of the Mæander, until it joins the southern end of the chain of Bourgas Dagh, and forms the southern boundary of the great plain of Hushak and Gobek.

5. The range to the south of the Mæander, which, commencing with Mount Latmus (lat. 37° 35′), extends past the lofty height of Cadmus to the eastward, where it merges into the Taurus chain, and continues with a general easterly bearing to the Euphrates. The drainage of the northern flank of this extensive range is effected, in the western portion, by the Mæander. Further eastward is the ancient district of Isauria, the drainage of which is collected into lakes and marshes with no apparent outlet. The waters on the south side of the Taurus range, flow by short courses into the Mediterranean.

6. The islands of Crete and Cyprus, though south of the district we are here describing, may be regarded as the crests of a submarine chain of mountains belonging to the same system of elevation, as the five parallel ranges above described.

The only important exception to the east and west direction, which prevails in the cases above enumerated, is found in the range which extends from Morad Dagh (lat. 38° 52′, long. 30° 9′) towards the S.E., where it assumes the name of Sultan Dagh, and forms the watershed between the sources of the Mæander and the great central plain of Asia Minor. This range connects the eastern end of the Demirji chain in an oblique direction to the middle of the Taurus range.

Classification of the Rocks of Western Asia Minor.

The rocks of this district, as far as we are acquainted with them, admit of being classed into the following geological groups, in ascending order :

A.—Sedimentary Rocks.

1. Micaceous schist and marble*.
2. Cretaceous System (Hippurite limestone, &c.).

* The Silurian rocks of the Bosphorus, described in Mr. Strickland's paper (vol. v. p. 385), pro-

3. Tertiary marine deposits.
4. Tertiary lacustrine deposits.
5. Modern aqueous deposits.

B.—Igneous Rocks.

1. Granitic rocks.
2. Greenstone, and older trap rocks.
3. Trachytic and newer trap rocks.
4. Modern volcanic rocks.

A.—Sedimentary Rocks.

§ 1. *Micaceous Schist and Marble.* (See Pl. III. figs. 1 to 8, and Sketches 12 and 13; also Pl. II.)

This series occupies a very important place in Asia Minor, constituting the greater portion of the mountain-chains which intersect the country*. It consists principally of micaceous schist, with which are associated beds of white or bluish crystalline limestone and stratified quartz-rock. The latter deposits seem to occur in no determinate order, but are interstratified with the micaceous schist, into which they often pass imperceptibly. Clay-slate is of very rare occurrence in this group of rocks, and we saw but few instances of *slaty cleavage* distinct from the stratification. Veins of white quartz are as frequent as in similar rocks of most other countries. The formation is very uniform in its characters, and the list of minerals which we found in it, is very scanty. On the whole, this group of semi-crystalline deposits bears much analogy to the gneiss and mica-schists of the Scotch Highlands, and may therefore, in the absence of definite evidence as to age, be referred provisionally to the primary or transition epoch.

The crystalline marbles of this formation are very generally dispersed over the country†. Sometimes they are pure white, but more commonly they are striped bluish grey in the lines of stratification,

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bably intervene in age between the schistose rocks and the Hippurite limestone. As they have not been noticed to the south of the sea of Marmora, we have omitted them in the above list. Fossiliferous rocks of this early age are unknown (as far as we are aware) in the whole circuit of the Mediterranean basin; and Constantinople may therefore be supposed to form the southern limit of the great geological basin of Northern Europe, throughout which these protozoic rocks are abundant.—H. E. S.

* Their elevation, however, appears to have taken place at very different periods; for though by far the most considerable portions were elevated into the present mountain-chains at periods of remote activity, and by the agency of granitic action, yet Mr. Hamilton observed many places along the coast, where these rocks had been elevated by outbursts of trachytic rocks, and at periods probably subsequent to the deposition of the cretaceous formation.

† Although the marbles of this country are in general associated with the mica-schist, yet it is possible, that in some cases they may be altered rocks of a more recent date.

or are wholly of the latter colour. Thin seams of mica often pervade the marble, which is then capable of being split into slabs; and they greatly assist the labours of the stone-mason. The vast abundance of marble in Asia Minor enabled its ancient inhabitants to carry architecture and sculpture to their highest perfection; and the numerous antiquities which remain in this interesting country, prove that in these arts the Asiatic Greeks fully equalled their kinsmen of Europe.

The quartz rock of this formation is more local than the crystalline marble. In its purest state it is white with a glassy lustre, and it is identical in appearance with the quartz rock which occurs in veins. Its origin however is very different, for it is distinctly interstratified with beds of micaceous schist. Laminæ of mica are often disseminated through the quartz, and when these predominate, the rock passes into regular micaceous schist.

As might be expected in formations of such antiquity, the stratification of this group is very irregular, both as to the amount and direction of the dip. The strike however is more constant, and commonly coincides with that of the mountain-range in which the observation is made.

The following are the principal localities where rocks of this group are exhibited:

(*a.*) *The island of Proconnesus* (*sea of Marmora*), *N. of the granitic ridge of Cyzicus.*—Large quarries of white marble exist here, and have given the modern name of Marmora to the island, as well as to the adjoining sea.

(*b.*) *Cyzicus.*—Near Erdek (ancient Artaki), at the south-western extremity of the promontory of Cyzicus, thick beds of argillaceous schist and crystalline marble occur, having a S. and S.W. dip. The upper portion of the promontory of Melanos, a mile S.S.W. of Erdek, consists of crystalline marble dipping S.W. and resting upon beds of argillaceous schist. The dip is quâquâversal, and evidently caused by the granite which forms the central mass of the Cyzicene peninsula.

(*c.*) *Aidinjik, S. of Cyzicus* (Pl. III. Sec. 1).—The strata here present a steep escarpment to the N., rising to the height of 900 or 1000 feet, while the hill slopes much more gradually to the S. down to the lake of Maniyas. The summit of these hills consists of a fine-grained crystalline marble, extensively quarried a little further eastward, whence marble was probably obtained to supply the wants of Cyzicus, one of the most splendid cities of antiquity in point of architectural decoration. The marble is interstratified with beds of schist of various colours, red, black, purple, yellow, and white, the whole dipping S. and S.E. by S. at angles of 70° or 80°.

(*d.*) *Mount Olympus of Mysia* (Pl. III. Sec. 2).—We did not ascend to the summit of this precipitous mountain. It appears however from the evidence of several travellers*, that a part at least of its loftier regions is composed of grey

* Fontanier, Voyages en Orient, Paris, 1829, p. 92. Seetzen, quoted in Walpole's Travels in the East, p. 113. M. Texier's personal communications.

granite. All the lower portions of the mountain which we explored, consist of rocks of the schistose group. The ravine above the town of Brusa exhibits the Section No. 2. The upper beds consist of fine-grained crystalline marble, dipping N.E. about 25°. The marble passes downwards into micaceous schist, approaching the texture of gneiss; and it is penetrated by quartzose veins, which are sometimes slightly granitic.

A long ridge of schistose rocks runs to the westward from Mount Olympus, between the Rhyndacus and the Lake of Apollonia. The same formation also occupies the S. side of the Rhyndacus, till we enter the lacustrine basin of Harmanjik. Throughout this district, the rugged hills of mica-schist and marble scarcely admit of cultivation, and are for the most part covered with forests of pine.

(*e.*) *The chain of Demirji* (Pl. III. Sec. 1, 4, 6, and Sketch 11).—We have no evidence of the structure of the western part of this ridge; but at Mumjik, on the Macestus, the pebbles and boulders, brought down from its higher parts, consist of quartz, gneiss, and a large-grained, micaceous granite. On the low part of this ridge, S.E. of Simaul (Sec. 6), these older rocks are concealed by younger sandstones. We had no opportunity of visiting the lofty insulated mountain of Ak Dagh; but its appearance so greatly resembles that of the mountains of Argæus and Hassan Dagh, as to warrant the supposition, that it may be a vast trachytic mountain analogous to those of Mont Dor and the Cantal. (See Geol. Proceedings, vol. ii. p. 651.) The ridge connecting Ak Dagh to Morad Dagh is composed of schistose rocks, and appears to be the eastern continuation of the Demirji range. This ridge, which bounds the plain of Azani on the S., sends off, along the W. side of the same plain, a branch, in which marble predominates. It probably joins the mountain of micaceous schist which we crossed between Taushanli and Gozuljah. (See Pl. III. Section No. 5.)

(*f.*) *Morad Dagh and Sultan Dagh.*—The branch ranging westward from Morad Dagh, between the Hermus and the Plain of Hushak, consists of schist with occasional beds of marble. The same formation composes Bourgas Dagh, a ridge which bounds the Plain of Hushak on the east, and is connected with Morad Dagh and Sultan Dagh. Along the west foot of this ridge, we found an abundance of stratified quartz rock, passing into micaceous schist.

(*g.*) *Mount Tmolus* (Pl. III. Sec. 3, 6, 12, and 13).—The portions of this range, which we visited, consist of micaceous schist with occasional beds of marble. At Nimphi, about fifteen miles east of Smyrna, mines of gold and silver are recorded to have been worked in the Middle Ages; and we can hardly suppose that the traditions respecting the golden sands of the Pactolus had not some found-

ation in fact, although they have been unproductive since the time of Strabo*. At present no metalliferous veins are worked in Mount Tmolus, but this may be owing to the paralysing effects of ignorance and despotism, rather than to the actual scarcity of the precious metals.

The chain of Tmolus expands to the south-west of the Catacecaumene, and a branch from it crosses the Hermus at Adala (Pl. III. No. 13), and is probably connected with the range of Demirji. About four miles west of Koola, we found some coarse garnets inthe micaceous schist,—the only examples of that mineral, which occurred to us in Asia Minor. The schistose rocks near Koola also abound in crystalline marble (Pl. III. No. 12), which was extensively quarried in ancient times near the village of Ghieurdiz; and three lateral ridges of the same schistose rocks extend to the northward in the district of the Catacecaumene, constituting, as will be hereafter shown, some of the most remarkable features of that district. At Aktash, between Koola and Takmak, a large crystal of oxide of titanium was found, and veins of the same substance are disseminated through the micaceous schist.

(*h.*) *Mount Messogis*, (Pl. III. Sec. 3).—The mountains around Ephesus, anciently called Gallesus, Prion, and Pactyas, abound in marble; and the ancient cities of Metropolis and Ephesus were built on solid masses of it. The town of Scala Nuova stands upon an insulated rock of blue marble, a portion of that branch of Mount Messogis which stretches toward Ephesus, while the other extends S.W. toward Mount Mycale. Marble is less abundant in the ridge of Messogis Proper, and none was noticed in crossing from Aidin to Tireh. The range here consists of pure mica-schist, occasionally penetrated with ferruginous matter. On the north of Tireh the hillocks, which jut through the alluvial plain of the Cayster, consist of schist and marble.

(*i.*) *Erythræ.*—In the bay of Ritri, opposite the island of Scio, Mr. Hamilton found a great development of grey and blue crystalline limestone, resembling that of Ephesus already described, and extending in a semicircular line round the ruins of the ancient town. In many places all traces of stratification were obliterated; but near the ruins of Erythræ, he found thin vertical beds of limestone and indurated sandstone, with veins and small masses of quartz. Some of the beds are much contorted, and the strike is nearly north and south. The Acropolis stood

* We were shown at Smyrna some specimens of rich copper ore, brought from the vicinity of Mount Tartali; but we could not learn whether they came from the schistose formation or from the Hippurite limestone.

For an account of Mount Tmolus and Mount Tartali, see Mr. Strickland's memoir on Smyrna, vol. v p. 393.

upon a lofty rock of red trachyte; and although the exact line of contact could not be traced, the marble was observed to be much shattered near the junction with the trachyte. The anchorage is formed by two large wooded islands, about $1\frac{1}{2}$ mile from the shore. The largest is called Karabagh, and consists of the same blue crystalline limestone; but apparently very thickly bedded, for no trace of stratification could be perceived.

(*k.*) *Boodroom* (lat. 37°, long. 27° 25′).—The high hills which rise behind the town of Boodroom (anc. Halicarnassus) consist of blue, compact, semi-crystalline marble belonging to this formation. In some places it is interstratified with thin bands of siliceous limestone, or cherty beds, which being less easily acted upon by the atmosphere, stand out more prominently than the rest. As far as our imperfect knowledge of the physical geography of Caria will enable us to judge, these hills belong to a S.W. branch of the fifth great mountain-chain before mentioned (p. 4), diverging off from the lofty range of Mount Cadmus.

(*l.*) *Cnidus* (lat. 36° 40′, long. 27° 22′).—The promontory of Cnidus, forming the extremity of the Doric Gulf to the south, Boodroom constituting that to the north, consists of thin-bedded limestone-shale, overlaid by thick-bedded blue marble; the dip being to the S. and S.W. from 45° to 60°. This formation was observed several miles up the promontory, and is composed of the following beds in a descending order:

The summit of the peninsula towards the west, consists of thin-bedded calcareous shale and a concretionary rock dipping to the S.W.; and of thick-bedded grey marble containing caves and fissures, many of which are covered or filled with stalactitic calcareous deposits, resembling in colour some varieties of oriental alabaster.

To the eastward of the hollow in which stood the ancient city, the marble reappears, dipping in the same direction, and is interstratified with a hard greenish sandstone grit.

The hills rise rapidly towards the E.N.E., attaining, at the distance of about two miles, a height of above 2000 feet. This summit is formed by a very narrow ridge of rocks, a quarter of a mile in length from N.W. to S.E., consisting of thinly laminated calcareous shales, dipping S.W. at an angle of 45°, and presenting an almost precipitous escarpment towards the N.E.

(*m.*) *Rhodes.*—The blue crystalline marble occurs frequently on the east coast of the island of Rhodes, near the town of Lindo, dipping 25° N.W. It forms high hills, against which the tertiary shelly limestone reposes, as shown in Section, p. 14. The Acropolis of Lindo is built upon strata of it, also dipping to the N.W. It occurs likewise further north, between Rhodes and Archangelo, where, besides the high range of hills about two miles from the sea, another low ridge of rocky points of the same formation rises up in the middle of the plain nearer the sea, forming a low ridge parallel to the coast. In one place, between Lindo and Archangelo, this rock was observed to become harder and schistose, and to pass into a hard black

crystalline limestone, with a slightly concretionary structure like the Silurian limestone of the Bosphorus; it likewise dips to the N.W., but at a much greater angle.

§ 2. *Cretaceous System.* (Pl. III., Sec. 1. 4 and 6.)

The fossils found in this group of rocks, prove it to be the equivalent of the "Apennine Limestone" of Italy, Dalmatia, the Ionian Islands and Greece*. The following are the localities at which we have evidence of its occurrence:

(*a.*) *The Northern Flank of the Olympus Chain.*—The south shore of the Lake of Apollonia (lat. 40° 2′, long. 28° 35′) consists of compact, fine-grained, pale yellowish limestone, resembling the Apennine limestone of the Ionian Isles. We did not succeed in finding fossils. It extends for about eighteen miles in a nearly straight line from E.N.E. to W.S.W., dipping at a high angle into the lake; and it apparently rests upon the schistose rocks which range from Mount Olympus to the westward. The same limestone occurs on the north side of the hills between the Lake of Maniyas and Susugherli (Sec. 1). It is accompanied by argillaceous shales and micaceous sandstones, which at the latter place form hills on both sides of the Macestus. Higher up that river, between Ildiz and Kebsit, is a range of schistose hills, in some places very micaceous, and in others resembling argillaceous slate. Huge masses of compact white limestone are exposed on the hill sides in several places, and appear to be allied to the hippurite limestone rather than to the schistose series.

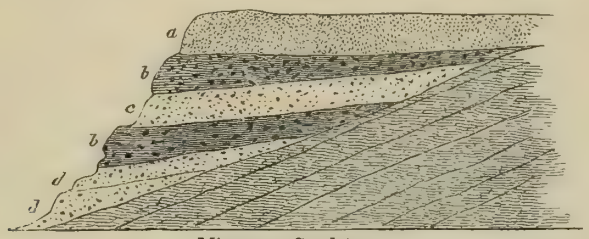
(*b.*) *The upper Basin of the Hermus.*—An arenaceous deposit which occurs in this district, we are inclined to refer to the newest portion of the secondary series. We first observed it on the north slope of a range of schistose rocks, which extend westward from Morad Dagh, between the Hermus and the Plain of Hushak (Pl. III. Sec. 4). It is well exposed in the ravine east of the village of Makouf, where it consists chiefly of brown micaceous sandstone, finely laminated; but it is not crystalline or compact, like the schistose formation above described. Some thin beds of soft white limestone were here noticed; and a little further north, a conglomerate of rolled pebbles of quartz, marble, mica-schist, &c., is interstratified with the sandstone.

On the south of the schistose ridge, between Sorkoum and Hushak (Sec. 4), is a zone of brown sandstone and quartzose conglomerate, dipping from 40° to 60° to S.W., which is probably referable to the same age. A similar sandstone occurs on

* For a description of the Apennine Limestone of Zante, see Geol. Trans., vol. v. p. 403; and for that of Greece, see the "*Expédition scientifique de la Morée,*" *partie géologique, par MM. Boblaye et Virlet.* Fol. Paris, 1835.

the north side of the Hermus, between the ridge of Demirji and the Catacecaumene. On the south of Simaul (Sec. 6) it occupies the whole surface of the ridge, which is there very low, and consists of thinly-laminated sandstone, containing mica, and breaking into large slabs. It extends thence southward for about five miles, where it is overlaid by a tertiary tufa. About eleven miles further south, the laminated sandstone reappears on the banks of the Aïneh-chai, dipping from 30° to 40° S. by W., and is covered unconformably by the horizontal tufa. The accompanying section is well exposed in this deep ravine, the hills on each side of which rise to the height of 600 or 700 feet.

Section, 7 miles N.E. of Selendi. Lat. 38° 45′, long. about 29°. (See also the description, p. 18.)



Micaceous Sandstone.

a. Peperite. *b.* Trachytic conglomerate. *c.* White marly quartz pebbles. *d.* Peperite, with boulders.

These sandstones appear at intervals on the sides of the river to the distance of six miles below Selendi. They are nearly horizontal, and on the south side of the Aïneh-chai have a slight northerly dip, reposing against a low ridge of saccharine marble, which ranges between that river and the Hermus. On the south of this axis, the sandstones again occur, dipping with a southerly inclination towards the Hermus; and are overlaid by horizontal beds of tertiary fresh-water limestone. The following section in descending order, is exposed about a mile north of the Hermus:

White marl of the tertiary formation	5 or 6 feet.
Alternate beds of marl and sand	20
Loose beds of sand and gravel, with pebbles of quartz-rock and schist.	30

The sandstones above described did not occur to us elsewhere in Western Asia Minor. They appear to be devoid of fossils, but are clearly younger than the schistose group, and older than the tertiary beds; and we have therefore preferred, on account of their comparative unimportance, to class them, for the present, under the Cretaceous system, than to assign them a separate place.

(*c.*) *The vicinity of Smyrna.*—The compact grey limestone with Hippurites and Nummulites, associated with greenish argillaceous and arenaceous shales, which

form the mountains around Smyrna, are among the best types of this formation, which fell under our notice in Asia Minor. They are described at length in a separate memoir. (Vol. v. p. 393.)

(*d.*) The *Island of Scio* and the peninsula of Kara-bornou consist of compact grey limestones, which we refer to this formation. These naked mountains present precisely the same dull grey appearance, which forms so peculiar a feature in the scenery of Greece and Albania, where similar rocks prevail.

(*e.*) *Sighajik* (lat. 38° 14′, long. 26° 50′).—The rocky peninsula which extends between Sighajik and Teos, and is connected with the main land by the low marshy plain, on which stand the ruins of Teos, consists of a greyish white limestone resembling scaglia, but having sometimes a much more earthy character. It dips slightly to the W. by S. It is generally thick-bedded, and very nearly resembles the lacustrine limestone near Smyrna. In places, it is underlaid by beds of sand and sandstone, containing calcareous concretions; and is sometimes thinly bedded, the strata being separated by slightly micaceous marly waybands.

(*f.*) *Syme* (lat. 36° 35′, long. 27° 52′).—The whole of the bare and rugged island of Syme consists of a greyish white compact alpine limestone or scaglia, with occasional nodules and bands of siliceous limestone. It is in general very thickly bedded, but is sometimes thin-bedded, the strata being separated by thin seams of marl or green sand. One of the authors (Mr. Hamilton), who was several days on the island, sought in vain for organic remains. The general stratification of Syme is horizontal; but toward the north the beds dip 80° N.N.W., whereas to the south the dip is S.S.E. The coast-line is rugged and deeply indented, and the general features and characteristics of the island closely resemble those of the island of Ithaca. The whole of the southern shore of the Gulf of Syme consists of the same formation. The limestone varies a little in colour, being sometimes a pale red. At the eastern end of the Gulf, it alternates with bands of pale red jaspery chert, dipping N.W. 50°; and it is in places much contorted. Further eastward, the dip is still greater.

(*g.*) *The Island of Rhodes.*—The greater part of that portion of the island which has been explored, consists of those rocks which, under the name of Scaglia, or Apennine limestone, have been considered the equivalents of the Cretaceous system of Europe. This formation is composed in the island of Rhodes of—1st, red and brown sandstone and conglomerates; and 2ndly, of whitish grey or cream-coloured and red scaglia limestone.

1. *Red and brown Sandstone and Conglomerate.*—These appear to constitute the upper beds of the system, and are found near the centre of the island. A red conglomerate sandstone occurs between Apollona and Embona, dipping S.S.W. 50°, and resting conformably upon white scaglia. Indurated red marls and hard sandstone grits also occur in the same locality. At the foot of Mount Atairo, to the N.N.W.,

is another bed of conglomerate, containing chiefly boulders of greenstone and a greenish granitic rock, together with rounded masses and pebbles of the grey scaglia, of which the neighbouring hills consist. The igneous rocks were not observed *in situ*.

2. *Scaglia Limestone.*—This formation is chiefly developed in the lofty ridges of Mount Atairo, the ancient Mons Atabyrius, which rises to a height of 3500 or 4000 feet above the sea. The summit is a narrow ridge above two miles in length from N.E. to S.W., which is nearly the direction of the axis of the island. The beds all dip uniformly to the S.E., at angles of 15° or 20°, and present a steep escarpment towards the N.W. The upper portion consists of thick-bedded grey scaglia without flints, and is underlaid by a thinly laminated, schistose limestone with tabular masses or beds of flint, below which again, the beds become thicker and the flints are nodular. These formations constitute the uppermost 900 feet of the mountain, below which the scaglia limestone is interstratified with a red calcareous shale or marly limestone, which is again succeeded by the thick-bedded limestone without flints.

The Acropolis of the ancient town of Camiro on the east coast of the island, six miles north of Lindo, is built upon an insulated table mass of white or cream-coloured limestone, very compact, and with rather a conchoidal fracture; and it has every appearance of having once been an island before the tertiary formations, by which its base is encircled, were raised above the surface of the waves.

(*h.*) *Deenair* (lat. 38° 3′, long. 30° 22′).—The same formation occurs at this place near the sources of the Mæander, where it contains numerous Nummulites. It is so extensively developed to the east and south-east, as to constitute the greater part of the Mount Taurus range; and Nummulites have also been found in it near Adalia.

The secondary deposits here described under one head, may ultimately prove to have been formed at various epochs, but we are at present too imperfectly acquainted with their organic remains to decide this point. The only fossils found by us, are Hippurites and Nummulites, and these indicate a very recent secondary date, equivalent to that of the Cretaceous system of Northern Europe. These deposits appear to have been affected by the same movements as the schistose rocks which underlie them; and all our evidence on the subject leads to the inference, that the mountain-chains of this country were elevated above the sea towards the close of the secondary period. It is this circumstance, which has caused that peculiar feature in the scenery of Asia Minor before adverted to,—the abruptness with which precipitous mountains rise out of horizontal plains (See antè, p. 3). We here find limestones of the Cretaceous age elevated into mountain-chains, which rival in altitude those of the Carboniferous and Protozoic periods in Northern Europe. Those younger secondary strata, which in Britain form tabular or undulating hills, and conduct us gradually from the plains of Essex to the mountains of Wales, have here undergone disturbances on the most gigantic scale. They have also acquired a compactness of texture much more analogous to the Protozoic than

to the Cretaceous rocks of Britain. The tertiary strata which have since been deposited around the bases of these mountains have undergone very little disturbance, and almost invariably retain their original horizontality.

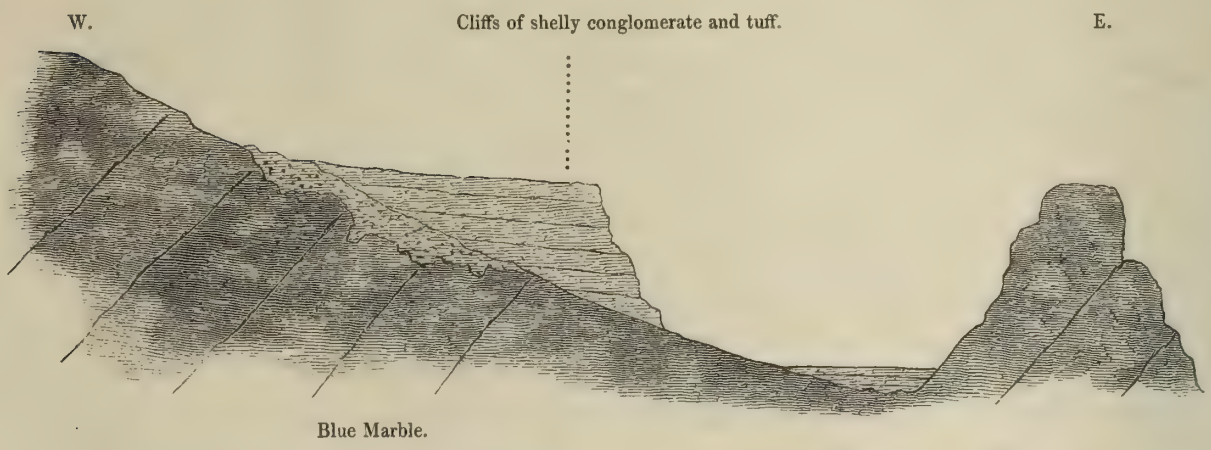
§ 3. *Tertiary Marine Deposits.*

Deposits of this class are of small extent in Asia Minor, and appear to be entirely confined to the vicinity of the sea-coast. We know of their existence at only the two following localities in Western Asia Minor:

(*a.*) *The Troad.*—The west coast of the Troad, and both shores of the Dardanelles, consist of horizontal strata of light-coloured limestones and marls. We had no opportunity of landing there; but as Olivier gives the names of several species of existing shells which he found in this deposit*, we infer that it belongs to the Pliocene group. A sandstone with Pectines is stated by Fontanier† to occur in Tenedos.

(*b.*) *The Island of Rhodes.*—The N.E. end of Rhodes consists of a yellow, concretionary, calcareous tufa, with beds of sand and gravel almost horizontal, and full of tertiary shells, of which the genera Pecten, Cardium and Venus are the most common. This deposit attains a height of 200 or 300 feet above the sea, forming in many places hanging terraces resting against the steep sides of the blue marble mentioned above‡. (See Wood-cut.)

Rhodes.



* Travels in the Ottoman Empire, vol. ii. ch. 2. † Voyages en Orient, vol. i. p. 9.

‡ Mr. Hamilton also observed in the ruins of Tripolis ad Mæandrum, nearly one hundred miles from the mouth of the river, several large blocks of a shelly tertiary marine limestone, which could not have been brought from any great distance; but he did not observe the rock *in situ.*

§ 4. *Tertiary Lacustrine Deposits.* (Pl. III., Sec. 1, 3 to 6, and 9.)

These deposits occupy a large portion of the surface of Asia Minor. We have already stated our belief (p. 13) that the schistose and cretaceous rocks, towards the close of the secondary period, were raised above the surface of the ocean, and formed that tumultuous mass of mountains which still intersects the country. It would seem, that the inequalities of surface thus produced, gave rise to numerous inland lakes, whose vast calcareous deposits denote a long period of comparative tranquillity. At length, by the slow denudation of their rocky barriers, aided probably by the convulsions incident to a volcanic country, these lakes were drained, and the rivers assumed the geographical positions which they still occupy. In the parts of Asia Minor which we visited, nearly every large valley was found to contain these lacustrine deposits ; but in the more narrow ravines of the mountain-chains, nothing of the kind was noticed. This fact may enable us to distinguish the modern valleys of denudation from those older depressions, which were caused by the original elevation of the mountains.

The lacustrine formations of Asia Minor consist, in general, of calcareous marl and white limestone. The latter is often identical in composition with the chalk of England, and the resemblance is further increased by the presence of beds and nodules of black flint. Sometimes the limestones are more compact, and approach in character the Italian scaglia or the Bavarian lithographic stone. Towards the margins of the lacustrine basins, the marls and limestones gradually become sandy and then gravelly, and not unfrequently traces may be found of a regular shingle beach*. (Pl. III. Section 5.)

The lacustrine strata are, with few exceptions, nearly horizontal, and seem in general to have remained undisturbed since the period of their deposition. The lapse of time however has subjected these deposits to extensive denudation, and sometimes nothing remains of them, but a few detached platforms, which skirt the sides of the valleys at the same level, and show the precise form and extent of these ancient lakes.

The organic remains which occur in these deposits, consist of lacustrine shells and portions of vegetables. They approach very closely to existing forms, though we do not venture to assert a completely specific identity in any of them with the present Fauna or Flora of Asia Minor. No remains of Mammalia or other Vertebrata were noticed during our rapid survey of these deposits ; and we wish to call the attention of future travellers to this desideratum in the geology of Asia Minor.

We now proceed to enumerate the localities at which we met with deposits of this class, though we do not pretend to assert the absolute contemporaneity of all these detached lacustrine basins.

(*a.*) *The basin of Moudania* (lat. 40° 23′, Pl. I.).—The country between Mount Olympus and the sea of Marmora is occupied by a tertiary formation, but no fossils occurred to us in it. Near Moudania it forms hills overlooking the sea, and several hundred feet in height. The similarity of the white limestone of the

* To the eastward of that part of the country, now more immediately under consideration, beds of selenite and gypsum occur in some of the upper portions of the formation, as between Sevrihissar and Afiom Karahissar.

beds of flint which accompany it, to the lacustrine deposits of Smyrna and other places, induces us to refer it provisionally to the same group. The formation extends to the Lake of Apollonia and reappears at Kirmasli, whence it sends a branch up the valley of the Rhyndacus as far as Kesterlek.

(*b.*) *Basin of Dundár* (lat. 39° 50′).—This basin is of small extent, occurring in a valley on the S.W. side of the Rhyndacus. The deposit is a soft, white, sandy limestone, dipping at the village of Bourmáh, about 10° E.S.E. Here also, having found no fossils, we are guided only by analogy in referring it to the lacustrine group.

(*c.*) *Basin of Harmanjik* (lat. 39° 47′).—This is bounded on the north by the schistose hills which form the base of Mount Olympus, and on the S.E. by the volcanic rocks of Eshén. It consists throughout of white limestone horizontally stratified. Like similar deposits in Auvergne and the Cantal*, it contains an abundance of black flint in beds and nodules; and considerable quantities of gun-flints are made there and sent to Constantinople. Near Haidár, at the northern limit of the basin, is a picturesque gorge, at least 600 feet deep, traversed by the Rhyndacus, which affords an admirable section of the horizontal strata on each side. The limestone contains a small turrited species of Paludina, resembling *P. acuta* (Michaud), or *P. stagnorum* (Turton). A species, similar in form but double the size, occurs associated with a Limnæa near the south boundary of the basin, about five miles from Harmanjik, and two from Eshén.

(*d.*) *Basin of Taushanli* (lat. 39° 35′).—The trappean rocks of Eshén (posteà, p. 23) separate this basin from the last. The lacustrine deposit, if such it be, has received considerable modification from the vicinity of the igneous rocks, which appear to have been in action during its deposition. In place of a pure earthy limestone, we have a peculiar kind of tufa or peperite, composed of particles of quartz imbedded in a felspathic cement, and accompanied by hexagonal crystals of hornblende. Near Taushanli this tufa becomes more calcareous, and contains angular fragments of jasperine rocks†. It is capped by a stratum of brown impure jasper, containing a large proportion of iron‡.

The alluvial plain of Taushanli is surrounded by platforms of this tufaceous deposit,—the scattered outliers of a formation once continuous. No organic remains were noticed.

* See Scrope on Central France, p. 25. Lyell's Principles of Geology, 3rd edition, vol. iv. p. 106, &c.

† Mr. Hamilton is of opinion that this tufaceous deposit, which he observed in many other parts of Asia Minor, does not belong to the lacustrine group, but is anterior to it, being in fact an accompaniment of the trachytic rocks which everywhere appear in its neighbourhood.

‡ This deposit of tufa and jasperine rocks is probably continuous with a similar district on the north of Kutahiyah, described by Mr. Fellowes in his "Excursion in Asia Minor," pp. 128, 129.

(*e.*) *Basin of Gozulják* (lat. 39° 25′).—We crossed this basin in going from Taushanli to Azani. It is filled with white limestone identical in appearance with English chalk, and containing strata of black flint. The scenery also strongly resembles that of our own chalk counties, consisting of rounded hills intersected by dry valleys, and covered with fir and juniper. No organic remains were noticed.

Near the village of Gozulják (Pl. III. Sec. 5) is a section showing the gradual transition of this white limestone into gravel, as it approaches the margin of the ancient lake.

(*f.*) *Basin of Azani* (lat. 39° 14′).—The ancient town of Azani, the interesting ruins of which are among the best-preserved in Asia Minor, stood in an alluvial plain near the source of the Rhyndacus, surrounded by mountain-chains of mica-schist and marble (Sec. 4). Around the bases of these mountains are beds of gravel, passing into white limestone. The latter rock approaches within three miles of Azani on the south, and has been extensively used in the construction of its ancient buildings.

The following species of shells were noticed in it:

1. Limnæa, a species closely resembling *L. longiscata*, Sow.
2. ———, a small turrited species like *L. fossaria*, Flem.
3. Physa, a small turrited species like *P. hypnorum*, Drap.
4. Planorbis, a large species like *P. cornea*, Drap.
5. ———— small, with five rounded volutions, like *P. spirorbis*, Mull.
6. ———— small, subcarinate, allied to *P. nitidus*, Mull.
7. Pupa, a small species.
8. Clausilia.
9. Paludina, a ventricose species like *P. similis*, Drap.

(*g.*) *Basin of the Macestus* (lat. 39° 20′).—The valley of the Macestus, between Kebsit and Boghaditza, is occupied by a horizontal formation of calcareous marl and white limestone, thinly bedded and of chalky texture, containing in some parts many nodules of flint. In the southern portion of the basin, the beds are broken up by the intrusion of igneous rocks, which will be described hereafter, p. 24, (Pl. III. Sec. 1). No organic remains were observed.

(*h.*) *Basin of Ghiediz* (lat. 39° 2′).—A deposit of white limestone fills the upper valley of the Hermus, and is contained between two ranges of schistose mountains which run westward from Morad Dagh. No fossils were noticed during our rapid survey. (Pl. III. Sec. 4 and 9.)

(*i.*) *Basin of Hushak* (lat. 38° 39′).—This is a lacustrine formation of great extent, bounded on the north and east by branches of Morad Dagh, and on the west by the mountains near Takmak, while to the south it extends to the Mæander, and is bounded by the continuation of the range of Messogis. The whole of this area is

a nearly level plain (Pl. III. Sec. 4), drained by tributaries of the Mæander, which flow in narrow ravines, deeply denuded in the lacustrine limestone, and discoverable only on a close approach. A remarkable case of the kind occurs near the town of Gobék. Here, a vast ravine, at least 600 feet in depth, is surrounded by cliffs of limestone in horizontal strata. At the bottom flows a meandering stream, probably the "Kopli-sou" of Tavernier. The time-worn cliffs resemble an assemblage of towers, castles and cathedrals, and present a scene which can hardly be depicted by the pencil or the pen.

In the more southern portion of this plain, where the formations have been cut through by the Mæander, the Banas-chai and the Kopli-sou, the subjacent beds of micaceous and argillaceous schists and crystalline marble of Mount Messogis, together with intermediate beds of sand and gravel, which everywhere underlie the lacustrine limestone, are well exposed along the borders of the ancient lake.

We found the following organic remains near Kalinkesé, in the central part of this basin (lat. 38° 30′):

1. Limnæa, apparently the same as No. 2 in the Azani list (p. 17).
2. Planorbis, ———————— No. 5 ————————
3. Paludina, ———————— No. 9 ————————
4. Minute seeds of Chara ("Gyrogonites").

(*k.*) *Basin of the Catacecaumene* (lat. 38° 35′).—The tertiary deposits in this basin, consist of horizontal beds of white limestone passing downwards (in the northern part of the basin) into volcanic tufa. The limestones have been deeply denuded by the Hermus and its tributaries, and now form a series of lofty plateaux, frequently capped by tabular masses of basalt, which will be described hereafter, p. 29 (Pl. III. Sec. 6, and Sketch No. 11.)

About nine miles south of Simaul (lat. 39° 5′, long. 29° 5′) the following section in descending order, of the horizontal tufaceous beds, was noticed:

a. Hard, volcanic tuff, slightly crystalline, with boulders and pebbles of trap, and numerous concretions of green marl	12 feet.
b. Soft, earthy, yellowish tufa, with small fragments of pumice	10 —
c. A hard crystalline bed, which, but for its stratification, might be taken for a slightly decomposed igneous rock	

These tufaceous beds are capped with white limestone, from beneath which they crop out in many places in the sides of the ravines. They rest unconformably on beds of secondary sandstone, as is shown in the wood-cut at p. 11. At the point where that section occurs, seven miles N.E. of Selendi (lat. 38° 45′), the lower part of the tufa, resting upon the sandstone, consists of a conglomerate with large masses and boulders of quartz, greenstone, and other primary and igneous

rocks, in irregular waved beds. The strata in ascending become finer-grained and more nearly horizontal, dipping 10° south. (See wood-cut, p. 11.) These appearances may be owing to the violent disturbance and gradual subsidence of a body of water, acted upon by volcanic forces.

On approaching the Hermus from Selendi, the tufaceous beds thin out, and the lacustrine limestone rests on the secondary sandstone. (Pl. III. Sec. 6.) This limestone covers an extensive tract on both sides of the Hermus, forming table-lands about 700 feet above that river. Between the Aïneh-chai and the ruins of Saittæ, it contains beds of tabular flint about a foot thick; and in one place, near a local outburst of basalt, a mass of hard brown siliceous rock, about 50 yards in extent, was found in the midst of the limestone, taking the place of the beds of flint.

Our attention was too much occupied with the volcanic phænomena of this interesting district, to search for organic remains in the tertiary limestone; but from the complete analogy of the formation to those deposits in which fresh-water shells were found, we have no doubt of its lacustrine origin*. The drainage of this ancient lake has doubtless been effected by the opening of the gorge in the schistose rocks near Adala, through which the Hermus flows. (Map, Pl. I., Pl. III., Sketch 13.)

(*l.*) *Basin of Sardis* (lat. 38° 30′, long. 27° 55′).—The greater part of this deposit has been removed by denudation, but some low hills of limestone yet remain on the south side of the Gygean Lake, and others to the east and west of Adala. A zone of sand and gravel, perhaps of a different age from the limestone, extends along the north flank of Mount Tmolus (Pl. III. Sec. 3), presenting a succession of broken hills and ravines, which, backed by the snowy heights of Tmolus, form a scene of the richest beauty. This gravelly formation is subject to rapid destruction; and the celebrated Acropolis of Sardis, which could once hold out against a Persian army, is now reduced at the top to an area of a few yards square, which a short lapse of time will probably diminish to a point. (Section 3.)

(*m.*) *Basin of Smyrna.*—The lacustrine deposits near Smyrna, with their imbedded shells and vegetables, are fully described in a paper devoted to the geology of that district. (See vol. v. p. 393.)

(*n.*) *Lower Vale of the Mæander* (lat. 38°).—It is with some doubt, that we cite this district in the list of lacustrine basins, as no fresh-water limestone was noticed in it; and the masses of gravel and sand which skirt the south side of Mount Messogis

* Mr. Hamilton, who, in the year 1837, succeeded in carrying his barometer across these plains, found that the elevation of the highest parts agreed, within a few feet, with that of the plain of Gobék and Hushak; he also thinks, that although separated near Koola by the eastern prolongation of Mount Tmolus, these two plains may be connected more to the N.E.; their elevation above the sea varying from 2000 to 2400 feet, the latter altitude being the elevation of the highest portion of the lacustrine formation of Koola.

might have been produced by the waves of the sea. However, they have so complete an analogy to those on the north side of Mount Tmolus, that we are inclined to refer them to the same origin, whatever it may be (Pl. III. Sec. 3).

In the valley of the Mæander, these accumulations of detritus form a zone of broken hills, many hundred feet in height, which flank the schistose range of Mount Messogis. They appear to have been afterwards modified by water at a lower level than that which originally produced them; for horizontal platforms of gravel rest against the sides of the loftier hills, at a height of about 200 feet above the alluvial plain of the Mæander. The ancient town of Tralles stood on one of these platforms, defended on three sides by an abrupt escarpment, and on the fourth by its citadel, which was placed on the summit of a lofty peak of indurated gravel and sand. The peculiarity of its situation is most accurately described by Strabo, lib. xiv. c. 1. The gravel consists of rounded pebbles of quartz and mica-schist, derived from the higher parts of Mount Messogis.

It is remarkable that of these tertiary deposits, so common elsewhere, no trace has been noticed in the valley of the Cayster. This extensive vale is completely insulated by the schistose ranges of Tmolus and Messogis, and the only exit for its waters is through a narrow gorge into the sea at Ephesus. The absence of these deposits renders it probable that the vale of the Cayster has been brought into its present condition at a comparatively recent period; or if contemporary with the other valleys of the country, we may suppose that, from the absence of a dam to retain its waters, no lacustrine deposit could accumulate.

§ 5. *Modern Aqueous Deposits.* (Pl. III. Sec. 2.)

Under this head we have to notice only travertine accumulations and river alluvions. Of the former, a remarkable instance occurs at Brusa (Pl. III. Sec. 2). The hot springs which rise at the foot of Mount Olympus have the high temperature of 184° Fahr.; and they constantly deposit travertine, a platform of which extends about two miles from the springs, along the foot of Olympus, into the town of Brusa. It is here about half a mile in width and 100 feet high. At this end, there are no thermal sources at present, and it is probable that they became stopped up by the calcareous deposit, and found a new exit at the point, where they now flow.

At Ilijah (lat. 39° 10′), in the upper valley of the Macestus, about seven miles east of Singerli, are some thermal springs of a very high temperature, which have formed extensive accumulations of fibrous and mammillated travertine. One source is ejected a foot and a half above the top of a mound of travertine which

it has accumulated, and which is approached by a natural bridge of the same substance formed across a stream from another spring. In one place, the water falls over a cliff eight or ten feet high, producing stalactites in its course.

The hot-springs of Hierapolis, in the upper valley of the Mæander, flow over a cliff which they have encrusted with white travertine and stalactites. The remarkable appearance here presented, has given the Turkish name of Bambouk-kalesi, or "Cotton Castle," to the town, and has excited the attention of many ancient as well as modern authors*.

Asia Minor presents some interesting examples of the geographical changes effected by the alluvia of rivers. The detrital deposits of the Mæander were so abundant as to excite the attention of Strabo. Since his time, the island of Lade, near which a naval action was once fought between the Persians and Ionians, has become a hill in the midst of a plain; the Latmic Gulf is changed into an inland lake; and the once flourishing town of Miletus, losing her commerce from this cause, has become a heap of ruins.

The alluvia of the Cayster have reduced Ephesus to the same state as Miletus. Her port, once the seat of commerce and civilization, is now a stagnant pool, separated from the sea by a marshy plain, which infects the surrounding district with malaria.

A similar fate perhaps awaits the now flourishing city of Smyrna. The Delta of the Hermus is fast advancing across the Gulf: a narrow channel only is at present open to shipping; and a few centuries may see that populous city, reduced to the condition of Ephesus and Miletus.

The absence of tide in the Mediterranean is doubtless the chief cause of the rapid extension of these alluvial deposits in historical times. The bays and estuaries not being cleansed by the daily reflux of the tide, the alluvial matter brought down by the rivers deposits itself close to their mouths, and their deltas are thus pushed into the sea with a rapidity, of which we have no examples in tidal oceans.

Under the head of modern alluvial formations, we may mention a singular lacustrine deposit in the valley of the Rhyndacus, above Kirmasli (lat. 39° 56′). A low range of tertiary limestone crosses the valley at that town, and is cut through by the Rhyndacus, which traverses a narrow gorge. A lake once existed on the upper side of the limestone hills, and has left considerable deposits of mud, sand and gravel. The opening of the gorge having drained the lake, the Rhyndacus has since had time to remove the greater part of the lacustrine deposit; but platforms of it still skirt one or both sides of the valley, at the height of 50 or 60 feet above

* See Strabo, lib. xiii. cap. 4. Vitruvius, l. viii. cap. 3. Chandler, Trav., vol. i. ch. 68. Laborde, Voyages en Orient. Fellowes, Excursion in Asia Minor, p. 283, &c.

the more modern plain in which the river now flows. Want of leisure prevented us from searching for organic remains in this deposit, but the appearances, which it exhibits, seem to refer it to the modern or newest tertiary epoch.

B.—Igneous Rocks.

§ 1. *Granitic Rocks.* (Pl. III. Sec. 1 to 3, and 6.)

Rocks of this class are rarer in Asia Minor than might have been expected in a country where schistose formations of great antiquity and igneous rocks of a later period are so largely developed. The only good example of granite which fell under our notice, is in the peninsula of Cyzicus (lat. 40° 25′, Pl. III. Sec. 1). This mountainous mass consists of a fine-grained grey granite, decomposing rapidly in consequence of the felspar which it contains, and thereby producing a luxuriant soil. It also contains large masses of hornblende or amphibole, and is sometimes traversed by veins of felspar.

This granite appears to have been elevated subsequently to the formation of the schistose rocks, which dip away from it, at Erdek to the S.W., and at Aidinjik to the S. and S.E. by S. (See Section 1.) The marble of the island of Proconnesus on the north, has probably been elevated by the same mass of granite.

From the occurrence of granite pebbles in the detritus at the north foot of the Demirji chain, near Mumjik (lat. 39° 7′, long. 28° 35′), we infer, that granitic rocks exist in the higher parts of that lofty range.

We have only to add on this head, that M. Texier, whose interesting researches in Asia Minor are in course of publication, informed us, that he had met with granite on the summits of Mount Olympus in Mysia, Mount Tmolus, and Mount Latmus near the mouth of the Mæander. (Pl. III. Sec. 2 and 3).

§ 2. *Greenstone, and older Trap Rocks.*

Igneous rocks, which can safely be referred to this class and period, are not of very frequent occurrence in the western parts of Asia Minor. They were observed by us at the following localities :

(*a.*) The promontory of Bozbornou, north of the Gulf of Moudania, consists at its western end of a greenish trap, sometimes forming rounded concretions, which at a distance resembled an artificial wall (lat. 40° 35′).

(*b.*) Immediately behind the town of Moudania a compact, green, trappean rock appears above the surface, and its decomposition has in many places produced a fine rich soil. This rock is however associated with tertiary strata, and is probably referable to a late epoch.

(*c.*) Another example of greenstone occurred between Kesterlék and Edrenos, on the south side of the Rhyndacus. It appears in the midst of the schistose formation, and is accompanied with red and brown jasper. We however saw no sections which exhibited its connexion with the schistose rocks, but we are disposed to think that the jasper is an altered rock intervening between the greenstone and the schist.

On the south side of the basin of Taushanli, above Karjitash, some trappean dykes were noticed in the schistose formation.

§ 3. *Trachytic and newer Trap Rocks.* (Pl. III. Sec. 1, 4, 6, 9, and Sketch 10.)

A remarkable feature in the geology of Asia Minor is the vast abundance of trachytic rocks, which have been erupted at detached points throughout the country. They appear generally to occur in the sides or bottoms of the valleys, and are frequently in contact with the tertiary formations.

No instance occurred to us of rocks of this class, in the higher parts of the schistose mountain-chains. From this circumstance, we consider the trachytic rocks of the country to be all, or nearly all, of the tertiary period; and it is probable, that their ejection was consequent on the breaking-up of the superficial crust by the elevation of the mountain-chains, at the close of the secondary period. Indeed, in some cases we have direct proof of the date of these eruptions by their having broken up, injected and altered the tertiary formations. It is remarkable, that in such cases the general horizontality of the tertiary strata remains undisturbed, the dislocations produced by the trachyte being confined to a few hundred yards around the focus of eruption. We may hence infer, how insignificant have been these volcanic operations in comparison with those forces, which could elevate the secondary formation into lofty mountain-chains.

We proceed to enumerate the chief localities at which we noticed this class of rocks:

(*a.*) On the north side of the lake of Apollonia, about three or four miles N.E. from the town of Abullionte (ancient Apollonia ad Rhyndacum), the hills consist of red porphyritic trachyte containing imbedded crystals of glassy felspar (lat. 40° 10′).

(*b.*) At Hammamlí, near Kirmasli (lat. 39° 56′, long. 28° 25′), is a mass of porphyritic trachyte of various colours. It forms an isolated hill not more than a mile in extent, rising in the midst of tertiary limestones.

(*c.*) Around the village of Eshén (lat. 39° 43′, long. 29° 20′), between Harmanjik and Taushanli, is an extensive patch of trappean rocks containing an abundance of iron ore, and occasionally traversed with veins of carbonate of magnesia. On the north side of these igneous rocks, on the road to Harmanjik, a dyke of com-

pact basalt, resembling greenstone, traverses lacustrine limestone containing Paludinæ and Limnææ.

Towards Taushanli these trappean rocks assume the character of a brown and grey trachyte, and form some considerable hills. They were probably erupted during the deposition of the tufaceous sandstones, which occupy the basin of Taushanli as before described (p. 16), the materials of which were probably ejected from the same craters in the state of ashes and cinders.

(*d.*) In the valley of the Macestus are several outbursts of trachytic rocks. (Pl. III. Sec. 1). About two miles south of Susugherli a mass of compact porphyritic trachyte stretches down from the hills on the west; and half a mile further south, at Tashkapu, is a considerable extent of white volcanic tufa, dipping slightly to W.S.W., and forming a perpendicular cliff, around which the Macestus flows. Hills of red trachyte with glassy felspar occur a mile to the south of Kebsit, and again at Kalbourja, six miles further south. One of these hills, of a conical form, rises far above the rest; and on its south side is a deposit of stratified volcanic sand and conglomerate, dipping S.W. and resting upon trachyte. A mile further south is a very talcose rock resembling serpentine, much decomposed, and breaking with an irregular, lustrous surface. These rocks rise in the midst of tertiary, lacustrine limestone above described, which, on the south side of the trachyte, is much disturbed, and is sometimes almost vertical. About three miles north of Boghaditza the same limestone is again elevated and broken by the protrusion of a small mass of igneous rock resembling a fine-grained granite.

The largest mass of trachytic rocks in the valley of the Macestus, commences on the south of Boghaditza (Pl. III. Sec. 1), and extends thence to the foot of the Demirji chain. The northern part of this trachytic mass is of a greenish colour, resembling that of the Bosphorus*. It contains veins of chalcedony, and is accompanied with a trachytic conglomerate. In one place, a large mass of contorted, calcareous, thinly laminated marl is caught up in the conglomerate. Further south, this trachyte varies in colour from white to green and red, and is mixed with an angular conglomerate, which often presents a stratified appearance. On the east of Singerli is a mass of porphyritic trachyte, with crystals of white glassy felspar and hornblende in a reddish brown matrix; and it much resembles the trachyte of Smyrna. It flowed in a *coulée* from the hills to the S.E.

The hot springs of Ilijah, described at p. 20, rise in these porphyritic rocks, which extend about eight or ten miles to the east of Singerli.

(*e.*) On the south side of the ridge of schistose rocks, between Azani and Ghiediz (Pl. III. Sec. 4), is an outburst of trachyte reposing on pumiceous sand and ashes.

* See Geol. Trans., vol. v. p. 388.

Further down, on approaching Ghiediz, several masses of igneous rock jut out amidst the lacustrine limestone. The most remarkable case appears at Ghiediz. (Pl. III., Sec. 4 and 9, Sketch 10.) This singularly situated town lies in a deep ravine, furrowed in the lacustrine limestone. On the lower side, the ravine is blocked up by a conical rock of compact and amygdaloidal basalt, containing green earth and augite, about 150 feet high, and riven to its base by a deep and gloomy fissure, the width of which, at the bottom, does not exceed two yards. This fissure affords an exit for the rivulet which descends the valley, and which would otherwise form a lake on the spot where the town stands.

On the north side, this basaltic mass has sent forth a *coulée* of columnar, amygdaloidal basalt about ten feet thick, resting conformably on beds of sand and gravel containing rolled pebbles of trachyte. (See Sec. 4 and 9.) This basaltic *coulée* may belong to a more recent period.

We regret, that our short stay at Ghiediz prevented our determining the relations of this volcanic mass to the surrounding lacustrine limestone. It is probably posterior to the lacustrine strata, for the latter contain no traces of volcanic matter. The beds of sand and gravel underlying the *coulée* were perhaps a local alluvium of the same date as the great lacustrine formations*.

(*f.*) *Trachytic rocks of Gunay* (lat. 38° 53′) (Pl. III. fig. 4).—These rise in the midst of the hills of secondary sandstone between Ghiediz and Hushak, about eight miles south of the Hermus. On the east side of the village of Gunay are some singular varieties of volcanic opal or pitchstone; and on the west is a well-defined *coulée* of grey trachyte with large crystals of felspar, which has flowed from the focus of eruption above, down a small valley in the sandstone hills.

(*g.*) *Trachytic hills east of Takmak* (lat. 38° 26′, long. 29° 8′).—This is a considerable cluster of abrupt conical hills standing at the western extremity of the plain of Hushak, and visible from the eastward at a great distance. We passed through them in going from Gobék to Takmak. This eruption of volcanic matter must have taken place anterior to the lacustrine formation of Hushak, for the gravel beds of that deposit, which abut against these hills on the east side, contain many boulders of trachyte mixed with pebbles of schistose rocks.

The hills are chiefly composed of trachyte of various colours, occurring either *en masse* or in angular fragments imbedded in a tufaceous paste. About four miles west of Karadjá Achmet Kieui, is a patch of stratified marl, sandstone and clay, enveloped and surrounded by the trachytic rocks. The beds are altered into the condition of quartz rock and Lydian stone.

(*h.*) *The Catacecaumene* (lat. 28° 30′).—The volcanic phænomena from which this

* In the Sections and Sketches, Pl. III., we have thought it best to colour this basaltic mass like the basalt of the *first period* in the Catacecaumene.

district derives its name, belong to a more recent epoch, and will be fully described in a subsequent part of this paper; but there are also igneous rocks of a different character and older date, which require to be noticed here. They occur in the northern part of the basin, from eight to sixteen miles north of Selendi, on the road to Simaul (Pl. III. Sec. 6), and consist of masses of trachytic rocks jutting out in the bottoms of the ravines, beneath the lacustrine formation. It was before stated (p. 18), that the lower portion of the lacustrine beds, in this part of the basin, consists of tufaceous deposits, which are doubtless connected in their origin with these trachytic eruptions. In some cases, the tufaceous beds have been broken up by the igneous rock; but in the only instance (thirteen miles north of Selendi) where the superincumbent limestone was seen in contact with trap, its stratification remained undisturbed; and therefore it is probable, that these eruptions were anterior to its deposition.

Between the ninth and tenth miles from Selendi, the tufa rests upon protruded masses of decomposing syenitic trap with a nearly vertical cleavage, and half a mile lower down, at the junction of two valleys, is a mass of trachytic conglomerate, with a solid trappean nucleus. Igneous rocks again rise from beneath the tufa at the eighth mile from Selendi, and have assumed, in consequence of decomposition, a great variety of colours.

(*i.*) About eight miles from Adala, on the road to Koola, is a small isolated hill of grey trachyte. It rises in the vale of Lydia, at the foot of the schistose mountains which form the north boundary of the valley of the Cogamus. A section, formed by a watercourse, shows that this trachyte is older than the platform of lacustrine gravel which reposes against it.

(*k.*) *Trachytic rocks of Smyrna.*—These extensive masses of igneous matter, which break up and overlie the lacustrine deposits of the Smyrna basin, are described at length in a memoir specially devoted to the geology of that district. (Vol. v. pp. 396, 401.)

(*l.*) *Fouges*, anc. *Phocæa* (lat. 38° 40′).—Igneous rocks, which have assumed a great variety of character, porphyritic, trappean and trachytic, form the chief ingredient of the hills which rise to the north of the little harbour of Fouges. They are associated with, and overlaid by various beds of tufaceous and pumiceous sands, which have sometimes assumed the hard, semi-vitrified character of the trachytic rocks themselves, and from which they can be scarcely distinguished. These beds all dip towards the south, and sometimes contain numerous cavities, which are either filled or coated with mammellary concretions of chalcedony.

(*m.*) *Ritri*, anc. *Erythræ* (lat. 38° 18′).—The Acropolis of Erythræ is situated upon an insulated peak of red trachyte, which rises abruptly to the height of two or three hundred feet, and although perfectly crystalline like that in the neighbourhood of

Smyrna, it has the appearance of being stratified, and dips to the north. In its range towards the north, the colour passes from red to grey : and the appearance of stratification is marked partly by colour and partly by cleavage. The trachyte is in contact with the blue marble, which it has elevated and shattered.

(*n.*) *Boodroom*, anc. *Halicarnassus* (lat. 37°).—About five miles to the S.W. of Boodroom is a lofty conical hill called Chifoot Kaleh, or Jew's Castle, nearly 1000 feet high, which rises directly from the sea. It consists of a reddish felspathic trachyte. The greater part of the promontory of Karabaghla, to the west of it, is composed of the same rock, as well as the islets of the coast. The hills between Chifoot Kaleh and Boodroom consist chiefly, if not entirely, of trachytic and pumiceous conglomerate, and horizontally stratified beds of volcanic sand, the contained fragments being generally angular, and varying in size and character.

§ 4. *Modern Volcanic Rocks.*

(Pl. II. and Pl. III., Sec. 4, 6 to 9, and also Sketches 10 to 13.)

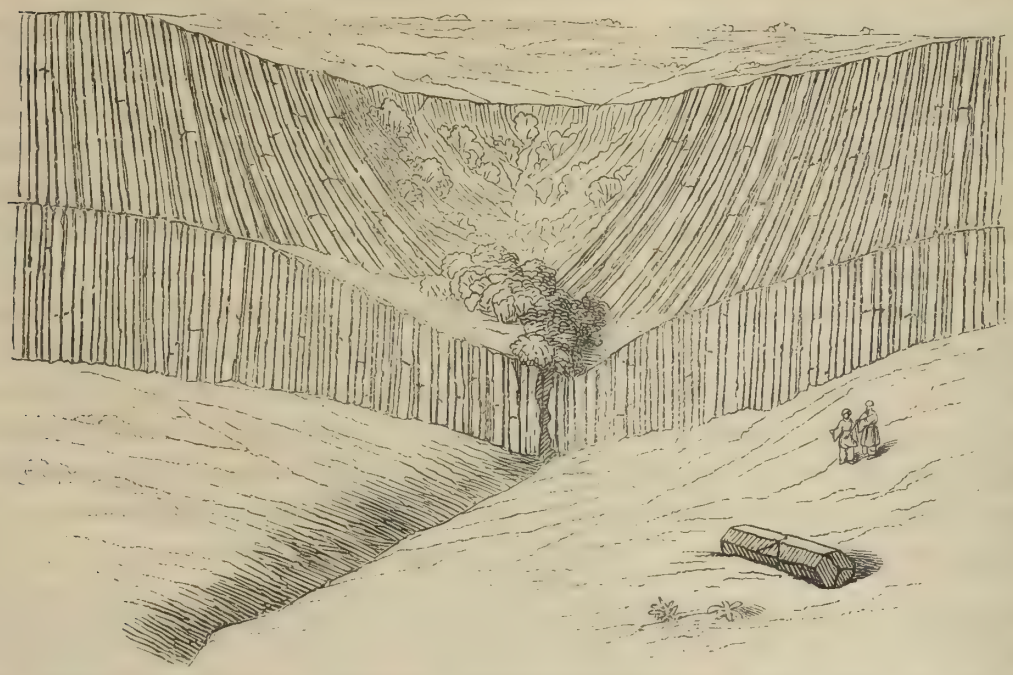
The only part of Western Asia Minor where phænomena strictly analogous to those of active volcanos are exhibited, is in that district of Lydia known anciently by the name of Catacecaumene, or the Burnt Country*. (See Map, Pl. II.) We term these volcanic products *modern*, from the relation they bear to the other formations of the country ; but it is certain that, compared with human history, their antiquity must be very great. No record of the activity of these volcanos existed in the time of Strabo, who however rightly infers their igneous origin from the phænomena which they present. Indeed, these phænomena are so striking as to excite the attention of every beholder, and feed the superstition of the ignorant ; and we accordingly find, that the ancient inhabitants laid the scene of Typhon's exploits in this region, while the modern Turks refer these mounds of cinders to the agency of Sheitan.

The Catacecaumene is described in a previous part of this paper (p. 18), as a tertiary lacustrine basin, surrounded by hills of schistose rocks. It is drained by the Hermus, which escapes at Adala through a narrow gorge in the schistose formation, the closing of which to a sufficient height would again convert the upper country into a lake. Numerous volcanic eruptions have taken place among the older rocks, which formed the southern margin of the basin ; and streams of lava, flowing from these foci, have overspread the lacustrine deposits.

* Strabo has considerably overrated the extent of this volcanic district, in giving it a length of 500 stadia, and a breadth of 400. Its real length is about eighteen or nineteen miles, and its breadth seven or eight, if we do not include the lava-stream which has flowed down the valley of the Hermus to Adala, which would increase the length to about ten miles more.

The outbursts of volcanic matter appear to be referable to three great periods. How long may have been their duration, or how long the intervals of repose between each, is buried in the tomb of time. All that we can now assert, is, that long intervals must have passed between each period of eruption; and that the latest eruption occurred antecedently to the commencement of traditional or authentic history.

The oldest series of eruptions took place at a time, when the bed of the lake presented a nearly level and unbroken surface, and before the first commencement of the excavation of the present valleys; for the basaltic rocks of that period invariably form the capping of the vast horizontal plateaux of tertiary lacustrine limestone. These eruptions could not have occurred long before the drainage of the lake; for if they had, we should find sedimentary deposits overlying the volcanic rocks, which is not the case; nor could they have occurred long after that event, for the valleys of denudation were not then formed. The eruptions of the second period were subsequent to the drainage of the lake, and to the excavation of deep valleys in the lacustrine deposits. Those of the third period are still more recent, and are distinguished by their entire identity of character with volcanos now in action. We will describe the localities and phænomena of these three classes of volcanic rocks in the order of their antiquity.



Section of columnar Basalt (for description, see next page).

1*st period.*—A mass of basalt of the first period caps the platform of lacustrine limestone on the north side of the Hermus for a distance of several miles, and may be seen in the distance in the sketch (Pl. III. fig. 11). The greater part of it splits into irregularly wedge-shaped masses; but in a hollow on the south side, there is a fine section of columnar basalt, divided into two beds. In the lower, the columns are uniformly perpendicular; but in the upper bed they diverge to each side with a slight curve, as seen in the accompanying wood-cut in the preceding page.

This vast tabular mass of basalt is here above 100 feet thick, but in general it does not much exceed 50 feet. A bed of soft sand intervenes in some places between the limestone and the basalt, but the junction-beds are in general obscured by a talus of basaltic fragments.

The summit of this basaltic plateau is about 800 feet above the bed of the Hermus, proving the vast amount of denudation which has taken place since the period of its eruption. The source from which the basalt has flowed is no longer apparent.

On the S.W. of this plateau, and on the opposite side of the Hermus, is a small insulated hill of horizontal limestone, also capped by basalt at the same level. Its base is encircled by streams of lava of the 2nd and 3rd periods, which have flowed since the excavation of the valleys. The limestone at the base of the hill has undergone alteration, and is converted into a yellow jasperine substance with a bright, conchoidal fracture (Pl. II.).

About five miles east by south from Koola, close to the foot of the schistose hills which skirt the lacustrine basin, is a small plateau of imperfectly columnar basalt, which is referable to the 1st period. It is seen in the foreground of the sketch (Pl. III. fig. 11). The lacustrine beds on which the basalt reposes, being near their junction with the older rocks, consist, in this place, of gravel and sand, derived from the schistose formation (Pl. II. and Pl. III., Sect. 8).

On the south side of the Hermus, about five miles N.N.W. from Koola, is another large insulated plateau of basalt, reposing on the lacustrine formation (Pl. II.).

2*nd period.*—To the second period of volcanic action, we refer the numerous conical hills of scoriæ and ashes, which cover the schistose ridges on the south of the lacustrine formation. The range of mica-schist and marble, which runs from east to west on the south of Koola*, sends off three nearly parallel ridges towards the north, and may therefore be compared to the letter E. (Pl. II.) The volcanic cones of the second period are scattered along this principal ridge and its three lateral branches, and many streams of lava may be traced flowing from them,

* These schistose hills form part of the northern base of the Tmolus range.

and descending the valleys of denudation in the lacustrine formation towards the Hermus.

The volcanic products of this period are distinguished by the smoothness of their outlines, and by the vegetation which clothes their surface. The cones of scoriæ are all low and flat, rising at an angle of about 20°; their craters have either disappeared, or are marked by only small central depressions, and all their asperities seem to have been smoothed down by time. The scoriæ which form them are sufficiently decomposed to admit of cultivation, and they are almost invariably covered with vineyards, producing the Catacecaumene wine, celebrated from the time of Strabo to the present day*. The streams of lava which have flowed from them, are level on the surface and covered with turf. The cones of this period are about thirty in number, and their position is indicated on the map (Pl. II.). We proceed to describe some of the more important examples.

On the most eastern of the three schistose ridges above-mentioned, are two conical hills of considerable magnitude, which are exhibited in the middle of the sketch, No. 11. (See also Section, No. 7.) Remains of a crater are very evident on one of these hills. A broad *coulée* of lava has flowed from each of them towards the north, and uniting has formed a plain about 200 feet above the Hermus, which has cut a passage through the northern extremity of the lava and the subjacent beds. This coulée is overlaid by a stream of lava of the third period, which will be afterwards described.

A great number of volcanic cones rise on the top of the central schistose ridge on the west of the plain of Koola (Sketch 12, Sec. 7). Most of them have a slight crateriform depression on their summits. Two or three of these cones, which stand at the eastern foot of the ridge, are partly surrounded by lava of the third period, flowing from Karadewit; and the *coulées* which descend from them towards the Hermus are overlaid in some places by lava of the same age.

The most western of the three schistose ridges, near the village of Megné (Sect. 7), is also covered with mounds of scoriæ, most of them destitute of lava-streams; but where these exist, they follow the slope of the country towards the north. On the eastern side of the ridge, near the summit, are some stratified beds of volcanic sand and ashes, sloping away from one of the cones.

About six miles N.W. from Megné, on the north side of a table-land of lacustrine limestone, is a stream of basaltic lava, which descends nearly to the Hermus. Its lower part is black and vesicular, but it becomes redder and more scoriaceous higher up. The crater from which it has flowed is not apparent. (See Map, Pl. II.)

* Of the fertility of many volcanic soils, when sufficiently decomposed, we see proofs in the vineyards of Vesuvius, Ischia, the Euganean Hills, &c.

3rd period.—The volcanic cones of both the second and third periods have been poured forth since the excavation of the valleys in the lacustrine formation; but their diversity, in point of age, is marked no less by the order of superposition than by the great difference in their state of preservation. The cones of the second period were described as being low and rounded in form, and covered with vegetation. Those of the third period, on the contrary, have all the features of volcanos now in action. They rise at an angle of 30° or 32°, and the ashes and scoriæ which compose them, are so loose as to render the ascent laborious. A few straggling shrubs and plants are the only vegetation which they produce; and the lava which has flowed from them, is as rugged and barren as the latest products of Etna or Vesuvius.

The volcanos of this third period are only three in number, and are nearly equal in size (Pl. II. and Pl. III. Sec. 7). They stand in a nearly straight line from W. by N. to E. by S., and at the distance of about six miles from each other*. It is remarkable, that each of them rises in the centre of one of the small alluvial plains which alternate with the three schistose ridges before-described, therein differing from the cones of the second period, all of which stand upon or near those ridges. We will describe them in the order in which they stand in the Section, No. 7.

The easternmost of these three cones is about a mile and a half N.N.E. of the town of Koola. Nothing can be more striking than the appearance of this town as viewed from the schistose ridge to the eastward. (See Pl. II., Pl. III., sketch No. 12; also No. 11.) On the right of the sketch, No. 12, is the cone of scoriæ and ashes, about 520 feet in height, denominated by the Turks *Kara-dewit*, or the "Black inkstand." An immense sea of black and rugged lava has flowed from its base, and spread over the surrounding plain. This eruption has formed a dam across the valley of Koola, and by stopping the natural drainage, has caused a marsh, which in wet weather is increased into a lake. To avoid the risk of inundation from this source, the town of Koola has been built upon the extremity of the lava-current, and is thus raised 15 or 20 feet above the plain.

The cone of Karadewit consists of scoriæ and ashes, principally of a reddish colour. On its north side is a small but very well-preserved crater; and a vast number of small conical hillocks of scoriæ have been thrown up amidst the lava which surrounds its northern base. The lava from this volcano flowed southward as far as Koola; but the larger portion of it descended in a northerly direction to the Hermus, which river has evidently been diverted from its course, and now makes

* These three craters are evidently alluded to by Strabo in his description of the Catacecaumene:—
Δείκνυνται δὲ καὶ βόθροι τρεῖς, οὓς φύσας καλοῦσιν, ὅσον τετταράκοντα ἀλλήλων διεστῶτες σταδίους.

a circuit round the north extremity of an overhanging cliff of lava nearly 50 feet high. The lava is vesicular and scoriaceous in the upper part, for about 6 or 7 feet. The next 20 feet are irregularly columnar, which structure gradually disappears in the lower part of the bed. The marls and limestones on the opposite or N.E. side of the river have been here much altered by their contact with the igneous rock, having been converted, in many places, into a yellow jasper-like substance, with a shining lustre and conchoidal fracture.

This lava encircles the base of several cones of the second period, and overlies the older coulées which they have sent forth (Pl. II.). In one place, 2½ miles N.N.E. from Karadewit, a narrow stream of lava has diverged to the east from the general mass, through a lateral valley in the schistose range, and has spread over the coulée from the easternmost cones of the second period before-described. The contrast between the lava-streams of the two periods is most striking.

The second of these recent volcanic cones rises in the plain between Sandal and Megné*, and is also called Karadewit (Pl. II. and Pl. III., Sec. 7). This hill consists of scoriæ and ashes resting on a more solid crust of red scoriaceous rock. The crater is quite perfect, and from 150 to 200 feet deep, the bottom being choked with large stones which have rolled down its sides. Many considerable caverns and hollows exist in the scoriaceous rock. The summit consists of a very narrow ridge surrounding the crater. A few small pine-trees grow on the sides of this cone, which, on the whole, bears more vegetation than the Karadewit of Koola. A stream of lava has issued from the west foot of the cone, and flowed northwards for about five miles to the Hermus; and a small crater, about a mile to the west of the great one, has sent forth a narrow *coulée* which soon joins the general mass. There is also a low flat cone to the south-east, apparently belonging to the 2nd period, from the crater of which a small stream of lava, about half a mile in length, has been poured forth, apparently at the same time as the eruption from the large cone. This lava is remarkable from having flowed over the margin of the crater, instead of bursting through the sides, like all the other lava-streams in the district. This is probably owing to its having flowed from the crater of an older and therefore more consolidated cone; whereas the recent cones, being formed of loose scoriæ and ashes, and much higher, were unable to support the mass of heated lava until it should overflow at the summit, and therefore yielded at their bases a passage for the lava.

The third or most western of the three great cones is called by the Turks Kaplan Alan (Pl. II. and Pl. III., Sec. 7). It is surrounded on all sides for more than a mile by the black and rugged lavas, which have flowed from its base, and render

* Near the centre of the plain of Megné a well has been sunk through the alluvial soil to the micaceous schist below.

the approach laborious. The cone itself is more clothed with vegetation than either of the other two, though it does not yield to them in the steepness of its sides, and the general freshness of its appearance. It possesses a very perfect crater, between 300 and 400 feet deep, surrounded by a ridge only ten or twelve feet wide at the top, and about half a mile in circumference.

On the north-west side of the great cone, a small one about half its height has been thrown up, with a regularly formed crater, but no lava appears to have flowed from it. On the west, several other small cones of scoriæ have been formed amongst the lava.

The lava from Kaplan Alan has chiefly issued from the east side, whence, spreading round both flanks of the cone, the two streams again united, and flowed down the plain to the west for about three miles; then turning south-west the stream descended a narrow valley for several miles, parallel to the Hermus, from which it is separated by a ridge of lacustrine limestone. At length, finding an opening into the valley of the Hermus, it followed the bed of that river along the narrow gorge in the schistose hills, whence, issuing at Adala, it spread for about a mile over the plain of Sardis, and at length terminated at the distance of at least thirteen miles from its source*. We were able to examine closely only the two extremities of this remarkable *coulée*, and we recommend the future geologist to follow its entire course from Kaplan Alan to Adala, as likely to afford him some interesting examples of the action of the river upon the lava.

The appearance of this rugged mass of lava, issuing from a narrow gorge in the schistose hills, and spreading over the fertile plain at Adala, is very striking. Half a mile above the town is the remarkable scene exhibited in the sketch No. 13 (Pl. III.). It appears that the Hermus, when its course was first impeded by the lava, was compelled to flow over the top of the *coulée*, the cavities of which have here been filled by river-worn gravel, forming a stratum on the surface of the lava. In course of time, the river has effected a passage between the mica-schist and the lava, and has denuded both rocks to a great depth. It now flows at the base of a cliff of compact lava about eighty feet high, imperfectly columnar in its lower part and scoriaceous above. Higher up in the gorge, the river has cut a channel completely through the *coulée* of lava, and changed its course from the right side to the left. Such are the effects which this river has produced in the lapse of ages. Yet so compact is the substance of the lava, that those parts of the *coulée*, which have escaped the action of the running water, are as rugged and naked as the latest eruptions of Vesuvius, and exhibit not the slightest tendency to decomposition.

* It is remarkable that this is the precise length of the lava-stream of the Puy de Tartaret in Auvergne, which has flowed down the narrow valley of the Couze to Nechers, in a manner strictly analogous to the case here described. See 'Scrope on Central France,' p. 117.

It is evident from the phænomena here exhibited, that however recent may be the appearance of the lava-stream, and of the cone from which it flowed, a very high antiquity must in reality be assigned to them. It is certain, from historical testimony, that no volcanic eruption has taken place in this country for at least thirty centuries, and how many more may have been required to enable the Hermus to denude the solid lava to the extent we now see, it is not easy to calculate. It would not indeed be fair to assume, that the whole of the present channel of the river between the lava and the mica-schist has been excavated to the depth of eighty feet since the flowing of the lava; for the rounded margin of a *coulée* commonly leaves a hollow between it and the pre-existing rock, which the river would naturally follow, and by undermining the columnar lava might produce a perpendicular cliff in less time than would at first sight be supposed. But when we find the river cutting *across* the *coulée*, and passing from one side of the lava to the other, we can assign no other satisfactory cause for this phænomenon than the mechanical action of the river, operating during vast periods of time, and gradually wearing down its bed to its present level*.

The freshness of appearance in the three great cones, the vast antiquity of which we have thus demonstrated, proves how small is the effect of atmospheric agency upon volcanic products, when unassisted by running water. Had these volcanos been ejected within the last ten years, the cones of scoriæ could hardly have been more perfect, the craters better defined, or the streams of lava more black, rugged and barren. Nor is this difficult to explain, when we remember, that the lava and scoriæ in this region seem to have scarcely any tendency to chemical decomposition, and that the rain which falls on the cones, being instantly absorbed by their porous soil, exerts no other mechanical force than the mere impact of the drops in falling.

These considerations render it difficult to explain the marked difference of appearance between the volcanic products of the second and of the third periods, on the mere assumption of a difference in their ages. It appears to us that a tenfold greater period of time, than has already elapsed since the ejection of the volcanos of the third period, would barely suffice to reduce them by atmospheric agency alone to the smooth and rounded forms presented by the cones of the second period; but

* The above observations, respecting the agency of running water in cutting through the lava-stream, are Mr. Strickland's. In justice to himself, Mr. Hamilton is obliged to state that he does not agree with the opinion, that the cutting across the *coulée* and the formation of the cliff are at all owing to the effect of running water acting upon the adamantine basalt. The very circumstance of the perpendicularity of the sides is an argument against it. He is rather inclined to attribute it to the fall of the basaltic masses in consequence of their having been undermined by the waters, the operation of which cause may have been hastened by fissures and crevices produced by the numerous earthquakes to which this country has at all times been exposed.—W. J. H.

if we suppose the latter to have been submerged beneath a body of water, either at the time of their ejection or subsequently, the explanation will be more easy. The action of water would soon obliterate all the sharp features of these mounds of ashes, and by filling up the cavities in the lava-streams with transported matter, would form that smooth and fertile surface which they now present. It is true that this explanation is not without its difficulties. The lake which existed here, before the basalt of the first period was poured forth, had long been drained, and deep valleys of denudation had been excavated in its bed, before the second period of volcanic eruption commenced. In order that the valley might be reoccupied with water to a sufficient elevation to cover the tops of the volcanic cones, the gorge at Adala would require to be blocked up to a height of perhaps 2000 feet, and the sojourn of this supposed mass of water must have been very transient, as we find no regular sedimentary deposits of any importance which can be assigned to it. Such a supposition involves an extensive flight into the region of conjecture, and many geologists would probably prefer explaining the wasted condition of these volcanic mounds, by means of ordinary atmospheric causes acting through an immense period of time*.

We have before alluded to the singular fact, that all the cones of the second period rise out of the ridge of schist and marble on the south of Koola, and its three lateral offsets (p. 29); while the three volcanos of more recent date occur in the plains which intervene between the several ridges (p. 31). This phænomenon may perhaps be accounted for by supposing, that several cracks and fissures were produced in the schistose ridges at the time of their elevation, through which the igneous products at first found vent; that in process of time, lavas having been injected into all the fissures and become cooled, the whole mass was rendered more compact than it was before; and therefore that when, at a later period, volcanic forces were again in action, the points of least resistance would be in the plains which intervened between the consolidated ridges, where the new eruptions would consequently take place.

It may be doubted whether the older series of eruptions supplied the forces which elevated the ridges themselves. The stratification of the latter is very irregular, and seems not to possess an anticlinal arrangement. Moreover, the undisturbed horizontality of the lacustrine beds in the vicinity, is scarcely compatible with any great subsequent disturbance of the schistose rocks.

* It may assist conjecture as to the relative and perhaps also the absolute antiquity of the three sets of volcanic eruptions above mentioned, if we remind the reader that the valleys have been denuded to the depth of 800 feet since the *first* period of eruption, of 200 feet since the *second*, and 80 feet since the *third*. The different density of the materials acted on in each case must of course be taken into the account.

Mineralogy.—To the mineralogist the Catacecaumene presents rather a barren field. The scoriæ and lava are of ordinary character; the latter contains olivine and augite, but no other crystalline minerals were observed.

Thermal springs.—In a valley about a mile north of the Hermus, and six miles N.N.E. of Koola, are some remarkably copious hot springs, rising in the lower beds of the lacustrine limestone. The water is perfectly tasteless, and forms no deposit or sediment whatever. The thermometer rose at the lowest spring to 123° Fahr. A short way to the east, in the centre of the ruins of an undetermined ancient city, are two other sources, at which the thermometer rose respectively to 133° and 137°. They rise out of a crevice in the calcareous tufa, and exhibit a slight development of sulphuretted hydrogen gas.

Comparison of the Catacecaumene with Auvergne.

No well-informed geologist can fail to be struck with the numerous and remarkable analogies between the Catacecaumene and the volcanic district of Central France, so elaborately described by Messrs. Scrope, Lyell, Murchison, &c. We will here present, in a tabular form, a few of the chief points of resemblance between the two districts. Some of these analogies may perhaps be only accidental coincidences, but the majority of them afford instructive examples of the universality of Nature's laws, whereby similar causes produce similar effects, even in the most distant regions.

Points of agreement between the Catacecaumene and Auvergne.

	EXAMPLES.	
	Catacecaumene.	Auvergne.
1. In both cases, clusters of extinct volcanos occur in the interior of continental tracts, remote from the sea.		
2. They are referable to several distinct periods, all subsequent to the commencement of the tertiary epoch.	Three periods.	Numerous successive periods.
3. They rise out of rocks apparently of the primary epoch.	Mica-schist.	Granite.
4. The direction of the volcanic zone coincides with the strike of the older rocks through which it is ejected.	E. by S. to W. by N.	N. to S. and N.N.W. to S.S.E.
5. The volcanos rise near the margin of a tertiary lacustrine basin, which they have partially overspread with basalt and lava.	Basin of the Catacecaumene.	Limagne d'Auvergne.
6. Eruptions of an early date have poured forth basalt over the lacustrine deposits, prior to their denudation.	Basaltic plateaux N.E. of Koola.	Plateau of Chateaugay, Gergovia, &c.
7. Extensive valleys of denudation have been excavated in the lacustrine deposits, which now form tabular hills capped with basalt.	Valleys of the Hermus and Aïnehchay.	Valleys of the Allier and its tributaries.

	EXAMPLES.	
	Catacecaumene.	Auvergne.
8. Eruptions of a later date have poured forth streams of lava, which have flowed down the valleys of denudation.	Cones of the 2nd and 3rd periods.	Puy de Nugère, La Vache, Gravenere, &c.
9. These eruptions have in some cases stopped the drainage of the valleys and produced lakes.	Marsh near Koola.	Lakes of Aidat and Chambon.
10. These newer streams of lava have been deeply excavated by the action of rivers now flowing.	Gorge above Adala.	Lava of Pont Gibaud, Jaujac, &c.
11. The more recent volcanos, though extinct from the earliest historic times, present all the sharpness of outline and barrenness of surface incident to volcanos now in action.	The two Karadewits and Kaplan Alan.	Puy de Pariou, Come, La Vache, &c., &c.
12. Thermal springs rise in the vicinity of the volcanic rocks.	Springs six miles N.N.E. of Koola.	Mont Dor, St. Nectaire, &c.

GENERAL CONCLUSION.

It would be rash, without much more extended observations on other parts of Asia Minor not visited by us, to attempt any generalization or theory on the successive formations of the different groups and systems of rocks in the Western part of Asia Minor. Most of those which have occurred to us as safe, in the present imperfect state of our knowledge and the scarcity of organic remains, have been introduced into the foregoing pages. There are however a few remarks which result from the observations on the coast of Ionia and Caria, which we think may with propriety be noticed here.

1. That the scaglia, or compact, white Alpine limestone, is more abundant in Rhodes and the southern parts of Asia Minor than in the northern or central districts of the peninsula. It is the same formation which constitutes the principal mass of the range of Mount Taurus, of which it may be considered as the western prolongation. Judging from the *Nummulites* found in it near Adalia, and at Deenair, near the source of the Mæander, it appears to be the same group, which extends through the Morea into the Ionian Islands.

2. The micaceous schist and saccharine marble, which are so extensively developed in the mountain-chains extending through the central parts of Asia Minor, as Mount Tmolus, Gallesus, Messogis, and along the coast of Ionia, gradually disappear towards the south, where they are replaced by the scaglia formation*.

3. The igneous and volcanic rocks, which in the central and northern parts

* The peninsula of Asia Minor may therefore be regarded as one vast axis of schistose rocks, flanked on the south by the Cretaceous System.—H. E. S.

of Asia Minor are found almost universally distributed, become extremely rare towards the south.

4. Trachytic or other igneous rocks are frequently found associated with the crystalline marbles, as at Erythræ and Boodroom, along the coast; and at Cyzicus and in the Catacecaumene, in the interior. But in the absence of organic remains, it is impossible to decide whether these marbles may not have had the same origin as the scaglia, and have been altered and crystallized by their proximity to the foci of igneous eruptions; or whether the volcanic outbursts have not raised to the surface, formations of a former period, and from a greater depth, in the immediate neighbourhood of their elevation*.

We will conclude this imperfect contribution to the geology of Western Asia Minor by comparing some of its more remarkable features with those portions of North-western Europe which have been most carefully explored. It will be seen that, notwithstanding the close analogy which we have shown to exist between some of the most recent geological phænomena of these two portions of the world, yet on the whole the geology of Asia Minor is more remarkable for its contrast than for its resemblance to that of Northern Europe. These discrepancies do not indeed affect those general principles of the science, which, established on the inductions afforded by our own and the neighbouring countries, have since been found to prevail throughout the world. Thus, the crystallized condition of the older sedimentary rocks,—their elevation on either side of granitic axes,—the disruption and alteration of strata by igneous injections,—the parallelism of mountain-chains within limited districts,—the absence of organic remains in the older strata, —their gradual approach to existing forms as we descend the chronological scale, —even the want of continuity between the secondary and tertiary series of deposits,—all these phænomena of Northern Europe find their counterpart in the region here described. But when we enter into greater detail, we shall find that Asia Minor, while it agrees in many respects with the geological types afforded by Greece, Italy, Spain, and the whole circuit of the Mediterranean as far as it is known, differs no less from those parts of Europe which lie to the north of the Alps and Pyrenees. For the sake of brevity and perspicuity we will recur to the tabular form in exhibiting these points of disagreement.

* Mr. Strickland is however of opinion, that the mica-schists and saccharine marbles constitute a distinct and well-marked formation, long anterior in age to the Scaglia. He considers it as an hypogene rock, which owes its present metamorphic character to causes far more extensive and deeper-seated than the volcanic eruptions which appear on the surface. He grounds this opinion on the constancy of character in this rock, whether in the vicinity of trachyte or otherwise; and on the fact, that the alterations produced in the tertiary beds by the injected trachyte, are very limited in extent and frequently imperceptible.—H. E. S.

In Western Asia Minor,	*In North-western Europe,*
1. The oldest organic remains belong to the cretaceous system*.	1. An immense series of fossiliferous strata underlies the cretaceous system.
2. The limestones and shales of the cretaceous system are compact, and sometimes semi-crystalline.	2. The limestones and shales younger than the carboniferous system are soft and earthy.
3. The mountain-chains have been elevated at the close of the secondary period.	3. The loftier mountain-chains have been elevated chiefly in the transition or early part of the secondary period.
4. The igneous rocks are chiefly of the tertiary period.	4. The igneous rocks are chiefly of the secondary period†.

It may become a question for the speculative geologist, whether all these discrepancies may not be resolved into a mere difference in the dates at which a similar train of events occurred in both these regions. Thus, if we assume that a series of vast subterranean commotions, accompanied by the exhibition of intense heat, has taken place in both countries,—obliterating the organic remains in the lower strata, and indurating the substance of the upper ones, elevating mountain-chains and setting in action a long train of volcanic operations,—we have only to suppose that in Asia Minor this period of subterranean energy occurred at the close of the secondary epoch, and in Northern Europe at its commencement; and the chief geological differences between the two countries may perhaps be explained without much difficulty.

* The Silurian rocks of the Bosphorus have been shown to belong to a distinct geological region. See note, p. 4.

† Auvergne and the Eifel form, we believe, the only exceptions to this proposition.

II.—*Description of some Fossil Remains of* Chæropotamus, Palæotherium, Anoplotherium, *and* Dichobunes, *from the Eocene* Formation, *Isle of Wight.*

By RICHARD OWEN, Esq., F.G.S., F.R.S.

[Read November 7, 1838.]

PLATE IV.

THAT the freshwater strata of the Eocene *formation* in the Isle of Wight were once trodden by Pachydermatous quadrupeds, belonging to some of the extinct genera established by Cuvier from the fossils of the corresponding strata of the Paris basin, is so well-established a fact, that some apology may seem necessary for laying before the Geological Society additional evidence of the existence in the above strata of such fossils, after the discovery of the remains of *Palæotherium* and *Anoplotherium* already made by Mr. Allan* and Mr. Pratt†.

Having, however, been favoured by the Rev. W. Darwin Fox with some fossil remains from Binstead and Sea-field quarries, Isle of Wight, apparently more numerous and better preserved than those which have hitherto been discovered in that locality, they seemed to possess sufficient interest to justify the present communication, as they establish not only the fact of the existence of more than one species of both *Palæotherium* and *Anoplotherium*, but likewise of the *Chæropotamus Cuvieri*‡, hitherto known only by Cuvier's description of very imperfect fragments discovered in the gypsum quarries of Montmartre and Villejuif.

The specimen of *Chæropotamus*, in Mr. Fox's collection, is the right ramus of the lower jaw, wanting only a small portion of the symphysis and the tip of the coronoid process. Pl. IV. fig. 1, 1a, and 2.

All the teeth are present which belong to this portion of the lower jaw, except-

* Dr. Buckland, in Annals of Philosophy, New Series, November 1825, vol. x. p. 360.

† Geological Transactions, 2nd Series, vol. iii. p. 451.

‡ *Chæropotamus Gypsorum*, Desm., *Chæropotamus Parisiensis*, V. Meyer. The latter naturalist has founded, upon some fossil remains from the Molasse of Rappenfluhe and Georgensmünd, two other species of this genus, which he calls *Chæropotamus Meissneri* and *Soemmeringii*. See *Die fossilen Zähne und Knochen von Georgensmünd*, 4to, pp. 51–55, 1834.

ing the second spurious molar and the incisors, if they really exist in the genus: the canine (?) is broken in the socket.

The fragments of the *Chæropotamus* which Cuvier* describes, consist of an incomplete base of the skull with six molar teeth on each side (Pl. IV. fig. 3 and 3a), and a small portion of a ramus of the lower jaw, with the canine (?) and two spurious molars.

The form of the teeth and the flattened surface of the glenoid cavity, afford sufficient proof of the pachydermatous nature of the animal, and its close alliance to the genus *Sus*. But the breadth of the glenoid cavity and the expansion of the zygomatic arches are greater than in any known species of Hog; the Peccari (*Dicotyles*) in these respects, as in the dental details, especially in the proportion and direction of its canine teeth, approaches nearest to the fossil.

Now the points in which the Cuvierian fossils prove that the *Chæropotamus* deviates from the Peccari, are those which indicate a nearer approximation in the extinct genus to the carnivorous type; and it is of great interest to find that the ramus of the jaw, so fortunately extracted in an almost entire state from the Isle of Wight strata, exhibits a structure, in the prolongation backwards of the angle of the jaw, which has hitherto been found to characterize, almost exclusively, the carnivorous Mammalia. Certain it is that no known pachydermatous or other ungulate species of Mammal presents this conformation. The figures (1, 1a, and 2, Pl. IV.) preclude the necessity of a detailed description of this process; it is more compressed and deeper than in the Bear, Dog or Cat tribe, and is not bent inwards in the way which peculiarly characterizes the marsupial jaws, and which so neatly distinguishes the Stonesfield Phascolothere. The condyloid process in the *Chæropotamus* is raised higher above the angle of the jaw than in the true Carnivora, and it is less convex than in the Hog or Peccari. In the size of the coronoid process the Peccari exceeds the true Hogs; and in that respect, as well as in the form and position of its canine teeth, makes a nearer approach to the carnivorous type; but in the *Chæropotamus* the coronoid process is still more developed in correspondence with the greater bulk of the temporal muscle, the size of which is indicated by the span of the zygomatic arches. In the wavy outline of the inferior border of the lower jaw, the Peccari alone, amongst the Hog tribe, resembles the *Chæropotamus*. The two detached molars of the lower jaw described by Cuvier, and which he compares with the third and fourth molars of the Babyroussa, are the fourth and fifth, or penultimate and antepenultimate molars, counting backwards, of the *Chæropotamus*, and correspond with the penultimate and antepenultimate grinders of the Peccari. The last molar of the lower jaw, in both the Peccari and Babyroussa, differs from the preceding in having two accessory,

* Ossem. Fossiles, Ed. 1822, vol. iii. p. 260; Pl. lxviii. li.

smaller and more closely approximated tubercles at the posterior part of the tooth, with a third small tubercle in the middle of the interspace between these and the next pair of tubercles. The Cuvierian fossils did not afford the means of making a comparison between the *Chæropotamus* and these species of the Hog tribe in this particular; but in the present specimen we see that the last molar of the lower jaw of the *Chæropotamus* presents the same additional posterior tubercles as in the Peccari, and thus affords an additional corroboration of the view taken by Cuvier with regard to its affinities. The other teeth correspond in every respect with the descriptions and figures in the *Ossemens Fossiles*; but the fossil here described yields another fact essential in characterizing the genus, and which the fragments in Cuvier's possession were too imperfect to afford, viz. the exact number of molar teeth in the lower jaw, which is twelve. Of these the three posterior teeth on each side are tuberculate, or true molars; and the three anterior ones are compressed and conical, or false molars; the latter have each two roots, and are relatively larger than in the Hog tribe. The tooth anterior to the grinders, and which from its shape Cuvier regarded as a canine, is situated closer to the symphysis of the jaw than in any of the existing *Suidæ*; but the Peccari, in this respect also, comes nearest to the *Chæropotamus*. The grinders, as in the Peccari, are narrower in the lower than the upper jaw. On the outer surface of the jaw, near its anterior extremity, the vascular foramina are numerous, as in the jaws of the Hog tribe*.

The occasional carnivorous propensities of the common Hog are well known; and they correspond with the organization of this genus, which offers the nearest resemblance among the existing Pachyderms to the carnivorous type of structure. In the extinct *Chæropotamus* we have another of those beautiful examples in Palæontology of links tending to complete a chain of affinities which the revolutions of the earth's surface has interrupted, as it were, and for a time concealed from our view. It is interesting also to perceive that the living sub-genus of the Hog tribe which most resembles the *Chæropotamus* should be confined to the South American continent, where the Llama and Tapir, the nearest living analogues of the Anoplotherian and Palæotherian associates of the *Chæropotamus*, now exist, and which was formerly inhabited by a genus—*Macrauchenia*, which connects the Llama with the Palæothere†.

* The dental formula of *Chæropotamus* may be thus expressed:—

Dentes prim.? laniarii $\frac{1-1}{1-1}$; molares spurii $\frac{4-4}{3-3}$; molares $\frac{3-3}{3-3}$; molares spurii compressiusculi, conici molares veri quadrituberculati, postremi in maxilla inferiore sextuberculati.

† Seeing that the Ungulate Mammalia make the nearest approach to the Carnivora in the Hog tribe, we naturally inquire to which of the groups of the Ungulata do the aberrant Carnivora tend. Now the

The fossils referable to other extinct Pachydermatous genera in the collection transmitted to me by Mr. Fox, do not require any detailed description. The following is a list of those which were determined without any doubt:—

Genus *Anoplotherium*,		
Sp. *commune.*	Anterior spurious molar, left side, lower jaw.	(Pl. IV. fig. 5.)
Sp. *secundarium.*	Second spurious molar, right side, lower jaw.	(Pl. IV. fig. 4.)
Genus *Palæotherium*,		
Sp. *medium.*	Posterior molar, lower jaw.	
ditto.	Portion of ditto, ditto.	
ditto.	Posterior molar, upper jaw.	
ditto.	Penultimate molar, upper jaw.	(Pl. IV. fig. 6.)
ditto.	Antepenultimate molar, upper jaw.	
ditto.	Anterior spurious molar.	
ditto.	Crown of a canine.	
ditto.	Complete incisor.	
crassum.	Second molar, right side, lower jaw.	
curtum ?	A molar tooth.	
minus.	Right ramus of the lower jaw with six grinders*.	
ditto.	Proximal end of the right radius.	
ditto.	Shaft and distal end of right tibia.	
ditto.	Portion of the base of the skull.	

Since examining the above collection I have seen the specimen from the Binstead quarries, now in the Museum of the Geological Society, conjectured by Mr. Pratt to belong to a species of Ruminantia closely allied to the genus *Moschus*. On comparing this fossil with the corresponding part of the *Moschus moschiferus*, which it resembles in size, I find that the grinders are relatively broader in the fossil, and that the last molar has the third or posterior tubercle distinctly divided into two by a middle longitudinal fissure, which is not the case in the *Moschus*. The grinding surface is less oblique in the fossil than in the *Moschus* or other Ruminants; and the form of the coronoid process of the lower jaw differs in a still greater degree than any of the above-mentioned particulars from that of the *Moschus* and other Ruminants, and strongly bespeaks the pachydermatous character of the fossil in question.

plantigrade genus *Arctonyx* immediately suggests itself to the mind; this genus is placed in the family of the Bears by Cuvier and Geoffroy St. Hilaire, the latter of whom also notices its points of resemblance to the Hog. Fischer sums up the characters of *Arctonyx* as follows: "*Rostrum suillum: oculi minuti: auriculæ breves: habitus et ungues Ursorum: cauda nudiuscula.* Genus *Feras inter Belluasque intermedium.*"—Synops. Mammal., p. 152.

* This interesting fossil was discovered in the Sea-field quarry, Isle of Wight, and is now in the possession of Mr. Henry Beech.

Now the extinct Pachyderms of the Paris basin, besides revealing forms which, as in the case of the *Chæropotamus*, tend towards the ferine group of Mammalia, contain other genera, which, in the modifications of both their dental and locomotive organs, lead away in another direction, and almost complete the transition from the pachydermatous to the ruminant order.

Among these genera the *Dichobunes* of Cuvier is the most remarkable, inasmuch as the posterior molars begin to exhibit a double series of cusps, of which the external present the crescentic form; and in one species (*Dichob. murina*, Cuv.,) the crescents are acute and compressed laterally, so that when viewed separately they might be mistaken for the teeth of a true Ruminant*. In the lower jaw of the *Dichobunes* the penultimate and antepenultimate grinders present two pairs of cusps, the last grinder three pairs, of which the posterior are small and almost blended together, so that when worn down they appear single. In this respect, as well as in the form of the ascending ramus of the lower jaw, Cuvier, who is not prone to exaggerated expressions, observes, that the *Dichobunes* prodigiously resemble the young Musk-Deer†.

Now with respect to the fragment of the lower jaw described and figured in Mr. Pratt's memoir, there is undoubtedly a close resemblance to the Musk-Deer; but the differences which I have pointed out forbid their association in the same genus. On the other hand, we perceive, both in the structure of the teeth and the form of the jaw, a much closer resemblance between the Isle of Wight fossil in question and the genus *Dichobunes*. But besides being somewhat larger than the *Dich. leporinum*, the ascending ramus of the lower jaw differs in form and approaches nearer to that of the true *Anoplotherium*. To this family (*Anoplotheridæ*) Mr. Pratt's interesting fossil without doubt belongs, and apparently indicates a new species, which, until the form of the anterior molars and incisors be known, might be referred to the genus *Dichobunes*, under the name of *Dichobunes cervinum*.

* La position et le nombre des pointes y (*Dichob.*) sont les mêmes que dans l'espèce précédente; mais les pointes sont plus aigues et comprimés latéralement, ce que tend encore davantage à les rapprocher des molaires des Ruminans. (*Ibid.* p. 64.)

† Or cette dentition, cette forme de branche montante, cette grandeur même, ressemblent prodigieusement à ce qu'on observe dans les jeunes *Chevrotains*. (*Ibid.* p. 61.)

III.—*Observations on the Fossils representing the* Thylacotherium Prevostii, Valenciennes, *with reference to the Doubts of its Mammalian and Marsupial Nature recently promulgated; and on the* Phascolotherium Bucklandi.

By RICHARD OWEN, Esq., F.G.S., F.R.S.

PART I.—*On the Thylacotherium.*

[Read November 21, 1838.]

Plate V.

THE ample experience which Comparative Anatomists possess of the truth and tact with which the illustrious Cuvier formed his judgement of the nature and affinities of an extinct animal from an inspection of part, or even a single fragment of its skeleton, would justify our not attaching much weight to a conflicting opinion, maintained on mere theoretical grounds, and without actual inspection of the fossil itself; but when the accuracy of one of Cuvier's interpretations is called in question by an anatomist so eminent as his successor in the chair of Comparative Anatomy, the confidence of geologists in their great guide in Palæontology becomes liable to be shaken, and an examination into the validity of such objections is requisite.

The doubts which M. de Blainville has published*, as to the mammalian nature of the animals represented by the well-known fossil jaws discovered in the Stonesfield oolite, rest,—first, on their being probably too imperfect to yield any conclusive evidence as to the class of animals to which they may have belonged; and, secondly, on an interpretation of appearances presented by casts of these fossils leading to conclusions opposite to those which Cuvier, and afterwards M. Valenciennes, derived from an inspection of the actual fossils.

It is in compliance chiefly with Dr. Buckland's request that I have undertaken to test the validity of these doubts, for which purpose he has transmitted to me from Oxford the two original fossils, each consisting of the ramus, or lateral half of a lower jaw; I have also re-examined the similar, but larger and more perfect

* "Doutes sur le prétendu Didelphe de Stonesfield." Comptes Rendus de l'Acad. de Sciences, Oct. 22nd, 1838.

fossil, described by Mr. Broderip*, and, since, liberally presented by that gentleman to the British Museum.

And first, with reference to the condition of these specimens, I am justified in stating, unequivocally, that each and all of them are sufficiently complete to furnish grounds to any anatomist, conversant with the established generalizations in Comparative Osteology, for determining therefrom the class, if not also the more restricted group of animals to which they have belonged.

Cuvier, after an examination of one of the jaws from Dr. Buckland's collection, pronounced "the animal to have been mammiferous, resembling an Opossum, although of an extinct genus, and differing from all known Carnivorous Mammalia in having ten molar teeth in a series in the lower jaw†." It is to be regretted, that, with the exception of the number of molar teeth, Cuvier did not specify the particulars on which he founded his belief that the jaw in question represented a new but extinct genus of mammalian, and probably marsupial quadrupeds.

This specimen (Pl. V. fig. 3), however, plainly exhibits,—first, a convex articular condyle (*a*) ;—secondly, an indubitable and well-defined impression of what was once a broad, thin, high, and slightly recurved triangular coronoid process (*b*), rising immediately anterior to the condyle, having its basis extended over the whole of the interspace between the condyle and the commencement of the molar series, and having a vertical diameter equal to that of the horizontal ramus of the jaw itself ;—thirdly, the angle of the jaw (*c*) continued to nearly the same extent below the condyle as the coronoid process reaches above it, and its apex is continued backwards in the form of a process ;—fourthly, the parts above-described forming one continuous portion with the horizontal ramus of the jaw, which is not compounded of three or four distinct pieces. It is true, with respect to the last proposition, that an inferior marginal groove (*d*) has been considered as evidence of the composite structure of the jaw under consideration ; but there is no other mark that could be interpreted as an indication of this reptilian structure, whilst a similar groove characterizes the lower jaw of the marsupial Myrmecobius and Wombat, and of some large species of *Sorex*.

Now these points, which may be presumed to have influenced Cuvier in forming his opinion of the nature of the fossil in question, are precisely those which arrested the attention of M. Valenciennes, when he examined the fossil itself, and which he has ably advanced in his endeavour to dissipate the doubts expressed by M. de Blainville.

Whence then, it may be asked, is the necessity of again describing these appearances, and of again urging their importance as evidence of the mammiferous nature of the Stonesfield jaw ? It arises from the circumstance that the Professor of

* Zoological Journal, vol. iii. p. 409, Pl. XI. 1828.

† *Loc. cit.* p. 409.

Comparative Anatomy at the Jardin des Plantes has declared, after an inspection of casts of the fossil examined by Cuvier and Valenciennes, that these anatomists have been deceived in all those points. M. de Blainville (*loc. cit.*) asserts that there is no trace of a convex condyle, but that, in its place, there exists an articular fissure, somewhat as in the jaws of Fishes ; that the teeth, instead of being imbedded in sockets, have their fangs confluent with, or anchylosed to, the substance of the jaws ; and that the jaw itself presents evident traces of the composite structure.

The point, therefore, which first demands our closest attention, is the actual condition in the Stonesfield fossils of the articular or condyloid process. Now it is scarcely necessary to observe, that the condyle of a lower jaw, independently of any other part, is sufficient to indicate whether it belongs to a mammiferous or oviparous animal. In the Mammalia it is convex or flat, in all Ovipara it is concave ; in the fossil Stonesfield jaw examined by Cuvier (Pl. V. fig. 3), in the second specimen of the same species (Pl. V. fig. 1) examined by M. Valenciennes, and in the lower jaw of another genus (Pl. VI. fig. 2), described and figured by Mr. Broderip*, a prominent, convex, articular condyle is more or less distinctly revealed. It is most entire and unequivocal in Mr. Broderip's specimen, which I shall subsequently describe. What M. de Blainville has mistaken for an articular fissure—"une sorte d'échancrure articulaire un peu comme dans les poissons,"—must be the entering angle or notch either above or below the true articular condyle.

In Plate II. fig. 1 of the Bridgewater Treatise of Dr. Buckland, this important part of the structure of the jaw is very accurately represented. The figure also of the jaw of the *Thylacotherium*, given by M. Prevost in the *Annales des Sciences*†, is by no means "tout-à-fait inexacte," as asserted by M. de Blainville ; but the form of the condyle is less completely displayed in this fossil than in the second specimen of *Thylacotherium Prevostii*, Val. (Pl. V. fig. 1). Although mutilated in both, what remains is situated in a line parallel with the crowns of the teeth, and projects beyond the vertical line dropped from the extremity of the coronoid process.

In the example examined by Cuvier, the form and extent of the coronoid process is indicated in a very clear and well-defined manner by the impression which it has left upon the matrix.

Now the coronoid process of the Opossum's jaw is plane on its inner surface, but slightly convex on the outer surface, the anterior margin of the process being produced externally in the form of a smooth convex ridge ; and both this ridge and the shallow depression behind it, are accurately represented in the impression which this portion of the jaw has left on the matrix in which it was imbedded.

* Zoological Journal, vol. iii. p. 408, Pl. XL.

† Avril 1825, Pl. XVIII. fig. 1, p. 389.

A similar impression would be made by the outer side of the coronoid process of the Mole's jaw, but not by that of any known reptile or fish.

In the Opossum's jaw it will be likewise perceived that a depression is continued forwards and slightly downwards from the condyle of the jaw to the foramen of the dental artery and nerve: in the fossil a corresponding depression of the jaw has left a convex elevation of the matrix, leading likewise from the condyle to the dental foramen; but this foramen, in the *Thylacotherium*, is situated relatively more forwards than in the *Didelphys*.

What therefore might at first sight seem to be an imperfection in the present fossil, affords in reality an additional clue for tracing out its true affinities. The fossil resembles the *Didelphys* in the breadth, the height, and the direction of the coronoid process; but, among the placental Insectivores, the *Gymnurus Rafflesii* sufficiently resembles in these particulars the present Stonesfield fossils, to prevent undue stress being laid upon the modifications of the coronoid process as indicative of their marsupial affinities.

The simple structure of the jaw of the Thylacothere, its convex prominent condyle, and the process continued backwards from the angle of the jaw, have been adduced by M. Valenciennes as establishing the truth of Cuvier's opinion of the nature of that extinct animal; and we have seen that all the fossils hitherto discovered justify such support. But these anatomical facts only go to prove the mammiferous and carnivorous, and not the marsupial character of the *Thylacotherium*: there is however a constant modification of the angle of the jaw, recognised by Cuvier* as peculiar to the family of Opossums (*Pedimanes*), and which I have found to characterize, not only that family, but all the marsupials hitherto discovered, and to distinguish them from their nearest congeners in the placental series: this character has not been taken into consideration in the inquiry into the nature of the present fossils by any of the able anatomists who have written respecting them, although, if co-existing with a convex condyle, it would be strong evidence of the marsupial nature of a fossil jaw, even if all the teeth were wanting.

In the carnivorous Marsupials, as the Thylacine, for instance, the lower maxillary bone resembles, in many respects, that of the corresponding species in the placental series, as the Dog: a similar transverse condyle is placed low down near the angle of the jaw; a broad and strong coronoid process rises high above the condyle, and is slightly curved backwards; there is the same well-marked depression on the exterior of the ascending ramus for the firm implantation of the temporal muscle; and the lower boundary of this depression is formed by a strong ridge extended downward and forward from the outside of the condyle. But in the Dog and other placental Carnivores (the Seals excepted), a process, representing

* Ossem. Fossiles, Ed. 8°, 1835, vol. v. p. 524.

the angle of the jaw, extends directly backwards from the middle of the above ridge, which process gives precision and force to the articulation of the jaw, and increases the power by which the masseter acts upon the jaw. Now, although the same curved ridge of bone bounds the lower part of the external muscular depression of the ascending ramus in all the Marsupialia, it does not in any of them send backwards, or in any other direction, a process corresponding to that just described in the Dog and other placental Carnivora. The angle of the jaw itself, in the Marsupials, is bent inwards in the form of a process, encroaching in various shapes and degrees of development, in the different marsupial genera, upon the interspace of the rami of the lower jaw. In looking directly upon the lower edge of the jaw, we see, therefore, in place of the margin of a vertical plate of bone, a more or less flattened triangular surface or plate of bone extended between the external ridge and the internal process or inflected angle. In the Opossums this internal angular process is triangular and trihedral, directed inwards, with the point slightly curved upwards, and more produced in the small than in the large species. In the Dasyures it has a similar form, but the apex is extended into an obtuse process. In the Perameles it forms a still longer process of a flattened form, extended obliquely inwards and backwards, and slightly curved upwards. It presents a triangular, slightly incurved and pointed form in the Petaurists, in which it is longest and weakest in the Pigmy species (*Acrobates*, Desm.). In the Potoroos and Phalangers the process is broad, with the apex slightly developed. It is bent inwards, and bounds the lower part of a wide and deep depression in the inside of the ascending ramus. In the great Kangaroo the internal margin of this process is curved upwards, so as to augment the depth of the internal depression above-mentioned. The internal angular process arrives at its maximum of development in the Wombat, so that the breadth of the base of the ascending ramus very nearly equals the height of the same part.

Now if the process from the angle of the jaw in the Stonesfield fossil be actually continued backwards, as M. Valenciennes describes, in the axis, or nearly so, of the ramus of the jaw, then such fossil would resemble the jaw of an ordinary placental carnivorous or insectivorous mammal, and the term *Thylacotherium* would be inappropriately applied to it; but in both the specimens of the fossil jaws to which that name has been restricted, and which present their inner or mesial surfaces to the observer, the angular process (Pl. V. figs. 1 and 3, *c*) presents a fractured surface; and we are led to conclude, therefore, that when the jaw was entire its angle was produced inwards or mesially; but whether to the same extent as in the Opossum and other Marsupials, or with a slight inclination, as in the Mole and Hedgehog, cannot be certainly determined in the present fossils. In these specimens, however, the apex of the angle only is fractured; while in the fossil

described by Mr. Broderip, the entire process, and consequently the angle of the jaw, which in the Marsupials constitutes this process, is broken away: in this jaw, likewise, the gentle convex line, continued from the condyle into the lower margin of the horizontal ramus of the jaw, is uninterrupted, precisely as in the jaw of the Marsupial (*Dasyurus viverrinus*) now on the table*, in which I have broken away, in a similar manner, the inwardly produced angle. In the fossils, something which projected inwards has evidently been broken off. The very circumstance of the angular process projecting inwards beyond the plane of the ramus of the jaw, would render it most liable to be broken off when the matrix came to be detached from the inner surface of the jaw; whereas, if it had been simply continued backwards, it might have been preserved entire; but this has not been the case in any of the fossils hitherto obtained from Stonesfield.

These appearances, in conjunction with the condyloid and coronoid processes forming parts of one simple, continuous, undivided plate of bone, would be sufficient to determine, not only the mammiferous, but the carnivorous, and to strongly indicate, in the *Phascolotherium* at least (Pl. VI. fig. 2), the marsupial nature of the Stonesfield fossils, if even every tooth and alveolar process had been destroyed.

Nevertheless, in a question of so much interest in the problem of the order of appearance of animated beings on our planet, it is well that these parts also are present, and in sufficiently good preservation in the fossils in question to yield important auxiliary proofs of their mammiferous, if not marsupial nature.

M. de Blainville alludes to a careful drawing of one of these jaws which represented the posterior molars as having "la forme en palmette, quinquelobée," a form which he observes is sufficient to expel them not only from the marsupial but the mammiferous series. To this it may be replied, that certain species of Seal, both recent and fossil, might, for the same reason, be argued to be non-mammalian.

The following is the exact condition of the teeth in the specimen of the *Thylacotherium* examined by Cuvier (Pl. V. fig. 3):—there are ten molars *in situ*, each with two fangs imbedded, as the seven anterior molars show, in deep and distinct sockets; there is an evident trace of the sockets of another molar anterior to those in place.

The molars very gradually increase in size from the first or anterior one to the sixth in the present specimen; the rest are equal, except the last, which is somewhat smaller. The crowns of all the grinders, except the second, third and fourth†,

* This specimen is now placed by the side of the jaw of the *Phascolotherium* in the British Museum.

† The teeth are here enumerated as they exist in the fossil, not with reference to the true dental formula.

are vertically split, and more or less of their internal grinding surface is broken away.

The *tenth molar* presents only the inner side of the middle external cusp, with part of the anterior cusp; a similar appearance would be produced in the true molar of a *Didelphys*, if the internal middle cusp and the posterior cusps were obliquely sliced away.

In the *ninth molar* the large middle external cusp is nearly entire to its sharp apex; part of the anterior cusp and the base of the internal posterior cusp are preserved: the same appearances would be produced in the true molar of a *Didelphys*, if the middle internal cusp and part of the anterior and posterior internal cusps had been obliquely truncated.

In the *eighth* tooth the fractured surface of the crown gives a view of the anterior and large middle external cusp, with part of the posterior external cusp.

In the *seventh* tooth the crown is more mutilated than in the preceding teeth; only a part of the anterior cusp and the base of the external cusp are visible; but the fracture displays the breadth of the crown, and corroborates the evidence afforded by the preceding teeth, and confirmed beyond question by the posterior molar of the second jaw (Pl. V. fig. 1), that these posterior molars were not provided, as M. de Blainville asserts, with mere compressed, five-lobed crowns.

In the *sixth* tooth the evidence of the complicated structure of the crown becomes indistinct: part of a large anterior and small posterior cusp are alone visible.

In the *fifth* tooth two similar cusps are present, but the points are broken.

The crowns of the *fourth*, *third* and *second* grinders are perfect, and clearly show that they are each divided into two, and not three, sub-compressed conical cusps, the posterior one being very much less than the other: these teeth precisely resemble the second and third false molars of the lower jaw in the Mole, as well as in some species of *Didelphys*. I cannot perceive the tricuspid structure given to these teeth in the figure in the Bridgewater Treatise of the jaw now described; that of M. Prevost in the *Annales des Sciences* is more exact in this particular, at least as regards the *third* tooth in place.

The minute cylindrical medullary canal (*cavitas pulpi*) is plainly visible in the anterior fang of both the second, third, fourth and fifth molars.

The crowns of the first and second premolars in the present specimen are broken vertically like the posterior teeth; but sufficient of the crown is preserved in both to show that it was unequally bicuspid, as in the two succeeding false molars.

The anterior false molars are altogether displaced; but traces of the alveoli, for the two short fangs of one of these, may be perceived at the broken anterior extremity of the present fossil.

The double fangs of the seven anterior molars in place are exposed by the breaking away of the internal plate of the ramus of the jaw: in the three following molars the beginning of the fangs are visible, slightly protruded from their sockets. The fangs extend half way through the vertical diameter of the ramus; their dense ivory is clearly contrasted both by its texture and deeper colour from the surrounding bone: so far from being anchylosed to this bone, as M. De Blainville asserts, they are clearly separated from it by a thin layer of a distinct colour from either, and which appears to be due to the matrix which has insinuated itself into the sockets of the teeth, as it has into the vascular canals of the jaw.

Lastly, it must be obvious to all who inspect this fossil and compare it with the jaw of a small *Didelphys*, that, contrary to the assertion of M. de Blainville, the teeth and their fangs are arranged with as much regularity in the one as in the other; and that instead of an argument in favour of the saurian nature of the fossil being afforded by this part of its structure, the distinct sockets and their double cavities, corresponding with the long and slender double fangs of the teeth, are conclusive against the saurian theory.

I proceed next to the description of the second specimen of the half-jaw of *Thylacotherium Prevostii* in Dr. Buckland's collection (Pl. V. fig. 1): this agrees in size and form with the preceding. Such teeth as are preserved in it, agree with the corresponding ones in the previous specimen: there can be no doubt that they both belonged to mature individuals of the same species and the same size. M. Valenciennes, after an inspection of this second example, declared it to be the left ramus of the lower jaw, having its internal side exposed to view: he founded his opinion on the presence of the orifice of the dental canal near one end, and of the articular surface of the symphysis at the other.

M. de Blainville, after an inspection of the casts of this example, came to a contrary opinion; he denies the existence of the orifice of the dental canal and of the symphysial articulation, and describes the specimen in question as being the external side of a compound jaw with an articular notch, like that of a fish or reptile. It has become necessary, therefore, again to subject this specimen to a severe scrutiny; and M. Valenciennes will pardon me for reiterating facts which he has so ably and accurately described, when he reflects that the progress of geological truth and the establishment of a sound theory of the succession of animal development in this planet would be impeded, if the doubts, cast upon his statements by so able an anatomist as his learned colleague, should remain untested by a second appeal to the specimen itself.

In this specimen the whole of the exposed surface of the lower jaw, with the exception of the coronoid, articular and angular processes, is entire; the smooth surface near the anterior extremity of the jaw is in bold relief, and slopes away at

nearly a right angle from the rougher articular surface of the elongated symphysis. It may be supposed that this symphysial articular surface (Pl. V. fig. 1, *e*), which at once determines the side of the jaw, might be obscured in a plaster-cast, but there is no possibility of mistaking it in the fossil itself; it is long and narrow, and is continued forwards in the same line with the gently convex inferior margin of the jaw, which thus tapers gradually to a pointed anterior extremity, precisely as in the jaws of the *Didelphys*, as well as in other Insectivora, both of the marsupial and placental series. Its lower margin presents a small but pretty deep notch, which possesses every appearance of a natural structure; and a corresponding but shallower notch is present in the same part of the jaw of the *Myrmecobius* (Pl. V. fig. 2, *f*). In the relative length of the symphysis, its form and position, the jaw of the *Thylacotherium* corresponds with that of the *Didelphys*, *Myrmecobius*, and *Gymnurus*. A greater proportion of the convex articular condyle is preserved in this than in the foregoing specimen, and it projects backward to a greater extent. The precise contour of the coronoid process is not so neatly defined in this as in the first specimen of *Thylacotherium*, but sufficient remains to show that it had the same height and width.

The exposed surface of the coronoid process is slightly convex: had it been the outer side, as M. de Blainville asserts, it would have been concave. The surface of the ascending ramus of the jaw is entire above the angle, whence we may conclude, that if the process from the latter part had been continued directly backwards, it would also have been entire; but the extremity of the angular process is broken off, proving it to have originally inclined inwards, or towards the observer: as, however, the greater part of the angle (*c*) is entire, it could not have been inflected to the same extent as in the *Didelphys*, *Dasyurus*, or the *Phascolotherium*, next to be described. A groove is extended from the lower end of the articular condyle forward to the orifice of the canal for the dental artery, where it divides; the upper branch terminates in the dental orifice; the lower and larger division (*d*) is continued forward near the lower margin of the jaw, and is gradually filled up half way towards the symphysis:—no one could mistake this smooth vascular groove for an articular fissure. There is a broader and shorter groove in the corresponding part of the jaw of the *Myrmecobius* (Pl. V. fig. 2, *d*), and a narrower groove in that of the Wombat. The alveolar wall of the posterior grinders makes a convex projection, characteristic of the inner surface of the ramus of the lower jaw. The posterior grinder in the present jaw (Pl. V. fig. 1) is fortunately more complete than in the first example, and shows a small, middle, internal cusp, with part of a large external cusp, both projecting from the crown of the tooth in nearly the same transverse line. The enamel covering the internal cusp, which is vertically fractured, is beautifully distinct from the ivory, and considerably thicker in proportion to the size

of the tooth than is the enamel or its analogue in the teeth of any species of Reptile, recent or fossil. The six molars, anterior to the one in place, are broken off close to the sockets; both the fifth and fourth false molars are entire: the anterior cusp has the same superior size, as in the first specimen. The thick enamel coating, and the silky iridescent lustre of the compact ivory, are beautifully shown in these teeth.

The third and second grinders are more fractured than in the first specimen, but sufficient remains to show that they possess the same form and relative size; but the most interesting evidence, as regards the teeth, which the present jaw affords, is the existence of the sockets of not less than seven teeth, anterior to those above described. Of these sockets the four anterior ones are small and simple, like those of the Mole, being more equal in their size and interspaces than in the *Didelphys*. The fifth socket contained a small premolar with double fangs, and so likewise the sixth and seventh. Thus the two false molars, with perfect crowns in the present specimen, are the eighth and ninth teeth, counting backwards, or the fourth and fifth of their class, viz. *premolares*, or false molars.

Thus, as regards the genus *Thylacotherium*, we have now evidence that its dental formula must include thirty-two molars in the lower jaw,—sixteen on each side: that these, instead of presenting an uniform compressed tricuspid structure, and being all of one kind, must be divided into three series, as regards their form: five, if not six, of the posterior teeth are quinque-cuspidate, and must be regarded as *molares veri*. Some of the *molares spurii* are tricuspid and some bicuspid, as in the Opossums; but they are six, if not seven, in number: anterior to these are four simple teeth, of which the fourth may be regarded as the representative of the canine, and the anterior three as incisors. Thus the *Thylacotherium* differs considerably from the genus *Didelphys* in the number of its teeth: indeed, at the time when Cuvier wrote, no mammiferous ferine quadruped was known to possess more molar teeth than the *Chrysochlore*, which has nine molars on each side of the upper jaw, and eight molars on each side of the lower jaw.

The *Chrysochlore*, however, is not the only Mammal in which the molars exceed the number usually found in the unguiculate Mammalia.

In the Transactions of the Zoological Society for the year 1836 (vol. ii. p. 149), Mr. Waterhouse published a description of an Australian Marsupial, forming the type of a new genus (*Myrmecobius*), and having nine molars on each side of the lower jaw, besides one small canine and three simple conical incisors*.

* The six posterior grinders of *Myrmecobius* are compound and multicuspidate; the three anterior ones are *molares spurii* and tricuspid; with the exception of the last, they gradually diminish in size as they advance forwards (Pl. V. fig. 2).

The teeth of *Thylacotherium* moreover differ from those of *Didelphys* not only in number but also in size, being relatively smaller. The teeth of *Myrmecobius*, besides their approximation in number to those of *Thylacotherium*, resemble them in their small relative size more than do those of *Didelphys*; but they are still smaller than in *Thylacotherium*, which, in this respect as well as in the structure of the teeth, holds an intermediate position between *Didelphys* and *Myrmecobius*. And it is interesting to find that the recent Mammal, which thus approaches most nearly the extinct *Thylacotherium*, should exhibit in the structure of its lower jaw, and of the articular cavity for the same, unequivocal evidence of its belonging to the marsupial family.

The *Didelphys Prevostii* being evidently, as Cuvier stated, a genus distinct from *Didelphys*, properly so called, and as great inconvenience arises in applying to it that name in the Linnæan sense, or as an equivalent to the term *Marsupialis*,—in which sense alone it has ever been so applied by the naturalists of this country,—M. Valenciennes has added to the value of his examination of the present fossil by proposing for it a distinct generic appellation. It would have been more prudent, perhaps, to have chosen one less descriptive than '*Thylacotherium*,' since the affinities of the fossil Insectivore to the marsupial order may be regarded as indicated only with a certain degree of probability, and as requiring further evidence before the desired demonstration can be attained. The determination of the particular order of Mammals to which the animal represented by these ancient remains is referrible, is a matter, however, of little moment, compared to the discovery of the class of vertebrate animals to which it belonged. In reference to this point, the evidence afforded by the two jaws, above described, decisively proves, in my opinion, that they belonged to a true, warm-blooded, mammiferous species, referrible also to the higher or unguiculate division of the class Mammalia, and to an insectivorous genus; with a probability, according to the present known fossils, of the marsupial character of such genus.

At a subsequent Meeting I propose to bring forward my observations on the more perfect fossil half-jaw, described by Mr. Broderip under the name of *Didelphys Bucklandi*, and of which the marsupial character is more strongly manifested.

As this, however, like the *Thylacotherium*, is generically distinct from the modern genus *Didelphys*, I shall describe it under the name of *Phascolotherium Bucklandi*.

The dental formula of the genus *Thylacotherium* is, as regards the lower jaw, as follows:

Incisors $\frac{?}{3-3}$; canine $\frac{?}{1-1}$; premolars $\frac{?}{6-6}$; molars $\frac{?}{6-6} = \frac{?}{32}$.

PART II.—*Of the Phascolotherium.*

[Read December 19th, 1838.]

Plate VI.

If the question of the existence of the remains of animals so highly organized as Mammalia, in the Stonesfield oolite, depended only on the evidence afforded by the half-jaws of the *Thylacotherium* described at a previous Meeting of the Geological Society, that evidence, I have contended, is amply sufficient to enable the anatomist to answer that question in the affirmative.

The remains of the split condyles in these fossils demonstrate their original convex form,—a form which is diametrically opposite to that which characterizes the same part in all Reptiles, and, indeed, in all Ovipara. The size, the figure, and the position of the coronoid process are such as have never yet been witnessed in any other than a zoophagous mammal, with a temporal muscle sufficiently developed to demand so extensive an attachment for the purpose of working a destructive carnivorous jaw.

The teeth are composed of dense ivory, with crowns covered with a thick coat of enamel; they are everywhere distinct from the substance of the jaw, and those of the molar series have two fangs, deeply imbedded in distinct sockets. These teeth are, moreover, of three kinds: the hinder ones are bristled with five cusps, of which four seem to have been placed in pairs transversely across the crown of the tooth. The anterior ones present a very different form, and have but two or three cusps in the same plane; the four anterior teeth were simple, and each with a single fang. Now these particulars have never yet been found united in the teeth of any other than a zoophagous mammiferous quadruped. The general form of the jaw corresponds with the more essential indications of its mammiferous nature just described.

The *Thylacotherium* being thus established in its true position as regards the primary divisions of the Vertebrate sub-kingdom, there next remained to be detected such secondary characters as might reveal the affinities of the fossil to some of the minor groups of the zoophagous and insectivorous Mammalia; and such seemed to be indicated by the fractured angle of the jaw. But the evidence that may be drawn from this appearance is not so clear and convincing as that which relates to the first and main argument.

Many naturalists and anatomists may concede the mammiferous character of the *Thylacotherium*, but may require further evidence in proof of its marsupial nature.

Still I must repeat, that the jaws of the Thylacothere, as at present known, resemble those of the small Opossums more closely than any other group of the mammiferous class; and in the number of the teeth, the Australian genus *Myrmecobius* offers the nearest approach to them.

It is, however, comparatively of little consequence to what particular order of Mammals the Stonesfield jaws belong, provided it can be certainly proved from them that they do belong to the class *Mammalia.*

The announcement of the fact of mammiferous remains in the oolitic formations, as it invalidated a received and general proposition relative to the first appearance of these remains in the component strata of the earth's crust, gave rise, in the minds of those philosophers who were unwilling to modify the general law so as to include the new fact, in the first place to doubts as to the antiquity of the matrix; and afterwards, when these doubts could no longer be maintained, to a denial of the high organization of the fossils.

With respect to the fossils themselves it is asserted,—

1st. That they are too imperfect to support any safe conclusion as to the class of Vertebrates to which they belonged; and that therefore, since all previous experience is contrary to the existence of mammiferous remains below the chalk or anterior to the Eocene period, the cold-blooded Ovipara ought to have the benefit of the doubt, and the fossils in question should be transferred to their low organized community.

The answer to this objection, which is founded on a view of casts only, is simply an appeal to the fossils themselves; the result of which has already been given as regards the *Thylacotherium.*

2nd. These natural hieroglyphics, though considerably time-worn, being allowed to be sufficiently entire to give, if rightly interpreted, the date of the strata on which they are inscribed, we have to consider the differences of opinion as to their real form and meaning. In other words, the objections to the mammiferous nature of the Stonesfield jaws rest not only on a difference of opinion as to their actual structure, but also on a different interpretation of admitted appearances.

It is asserted that the jaws in question must belong to the cold-blooded Vertebrates, because the articular surface is in the form of an entering angle. My answer to this has been, that the articular surface is supported on a prominence, and that that prominence is convex; and that a convex condyle is met with in no other class of Vertebrata, save in the Mammalia.

It is asserted, again, that the teeth are all of an uniform structure, as in certain reptiles. But this argument, in like manner, falls to the ground on reference to the fossils themselves; the contrary being the fact, and the actual structure of the teeth strongly supporting the mammiferous theory of the fossils.

We have next to consider those arguments which have been founded on admitted structures.

The advocate of the mammiferous nature of the Stonesfield Thylacothere allows that it has an unusual number of molar teeth, it may be twelve, true and false, on each half of the lower jaw; but he denies the inference, that, therefore, this half-jaw has not belonged to a Mammal. There is not sufficient constancy in the number of the teeth in the Mammalia, or even in the carnivorous or insectivorous subdivisions of that class, to render the excess of teeth in the Thylacothere of any value as an indication of its classial relations. Among the placental Carnivora the *Canis Megalotis* has constantly one more grinder on each side of the lower jaw than the usual number. Among the Insectivora the Chrysochlore has also eight instead of seven molars in each ramus of the lower jaw. Among the Marsupiata the genus *Myrmecobius* has nine molars on each side of the lower jaw. Some of the insectivorous Armadillos and of the zoophagous Cetacea offer examples of a combination of still more numerous and reptile-like teeth, with all the true and essential characters of the mammiferous class. The anatomist, contending for the saurian nature of the Stonesfield jaws, must have felt the weakness of his cause when he appealed to the number of the teeth in that fossil for its support.

All the spurious molars of the *Thylacotherium* have two well-developed fangs: but this fact has also been adduced as an objection to the Cuvierian determination of that extinct animal. The greater number of the spurious molars, however, in every genus of the placental *Feræ*, have two fangs, and in the marsupial Mammalia, as well as in the Mole, and some other Insectivora, the whole of the false molars invariably possess two fangs, and this structure as little co-exists with a complicated crown of the tooth as in the extinct Thylacothere.

If the ascending ramus of the Stonesfield jaws had been absent, and with it the evidence of their mammiferous nature afforded by the condyloid, coronoid and angular processes,—the structure of the teeth, and especially the implantation of the molars in distinct sockets by means of long double fangs, would, nevertheless, have yielded proof that the fossils in question were the remains of a species referrible to the highest class of animals. Since a Shark's tooth is never implanted in a socket, its form, whether it have a bifurcate base or not, cannot afford any argument for the non-mammalian nature of the *Thylacotherium*: the saurian nature of the so-called *Basilosaurus* is too problematical for the attachment of any value to an objection founded on the two-fanged structure of its teeth*.

When also it is recollected that Cuvier described and figured (after Garriga) the teeth of the *Megatherium* as having two fangs, and when the origin of that

* See Brû's Descripcion del Esqueleto de un Quadrupedo muy corpulento y raro, &c. Folio, Madrid, 1796.

mistake is kept in view, the anatomist, anxious after truth, would pause before he accepted the reputed structure of the molars of the *Basilosaurus* as valid proof of so anomalous an exception to the condition of the teeth characteristic of the class *Reptilia*, if even the Basilosaur should prove to be a true Saurian. In the teeth of the *Megatherium* the appearance of the double fang was produced by an accidental fracture in the axis of the tooth, displaying the two converging sides of the simple conical cavity, which, as in the teeth of the larger Saurians, occupies the base of the really simple and fangless tooth of the Megathere.

Until, therefore, the teeth of the *Basilosaurus* shall have been examined with a view to the possibility of this mistake, and their size, form and relations to the jaws have been described, the simple statement that such an extinct animal had teeth with double fangs, can have little force against the argument for the mammiferous nature of the Thylacothere, founded on the structure of its teeth*.

The objection to the mammiferous character of the Thylacothere founded on the colour of the fossil, as indicative of a proportion of animal matter originally therein present, and presumed to be such as is found only in the cold-blood Vertebrata, will have but little weight with the geologist practically acquainted with fossil remains. The dentine of the Mastodon's grinders commonly exhibits a colour much more nearly approaching to jet black than is presented by any tooth of the Thylacothere. On the other hand, there are numerous fossils of both reptiles and fishes, which, from the accident of their matrix, offer evidence of a much less original proportion of the animal matter than is conjecturally assigned to those of the Thylacothere.

There remain then for discussion the arguments for the saurian nature of the Stonesfield fossils, founded on the appearance of a compound structure observable in them.

As these appearances are more numerous and imposing in the jaw of the *Phascolotherium* about to be described, I have reserved their consideration to the present opportunity, repeating only, with respect to the Thylacothere, that the only trace of this structure in the jaw of that fossil is due to a mere vascular groove running along its lower margin; and that a similar structure is present in the lower jaw of some species of the Opossum, in the Wombat, *Myrmecobius*, and in that of the *Sorex Indicus* and of other Mammalia.

Description of the Half-jaw of Phascolotherium Bucklandi. Pl. VI. fig. 2.

The fossil on which this genus is founded is the right ramus of the lower jaw, having its external

* Since this paper was read, I have had the unexpected gratification of being able to determine the mammiferous, and probably cetaceous nature of the so-called *Basilosaurus*. See *posteà*, p. 69 of the present volume.

surface imbedded in the oolitic matrix, and its inner or mesial surface exposed to the observer. It is the fossil described and figured by Mr. Broderip in the Third Volume of the Zoological Journal (Pl. XI.), in which its generic distinction from the Stonesfield fossils of *Thylacotherium* is distinctly pointed out, and the name of *Didelphys Bucklandi* given to it only 'for the sake of convenience and perspicuity;' the word *Didelphys* being here used in its widest sense, and the author expressly stating that it would perhaps be presumptuous in him to pronounce on its generic identity with the group of Marsupials, to which the term *Didelphys* is restricted by Cuvier.

In presenting another description of this interesting fossil to the scientific world, I have to offer the same apology to Mr. Broderip as to M. Valenciennes, in reference to the *Thylacotherium*. And the imposition of a distinct generic name on the *Didelphys Prevostii* by MM. Agassiz*, de Blainville and Valenciennes, has, in some measure, compelled me to take the same step in reference to the *Didelphys Bucklandi*, since I shall be able to prove in the sequel, that this fossil offers characters which distinguish it generically, not only from the *Didelphys Prevostii* or *Thylacotherium*, as Mr. Broderip has already pointed out, but also from the true genus *Didelphys* of modern Mammalogists, to which, nevertheless, it has a much nearer affinity.

The condyle of the jaw of the *Phascolotherium* here described (Pl. VI. fig. 2. *a.*), instead of being vertically split, as in the specimens of *Thylacotherium*, is fortunately entire, and stands out in bold relief from the oolitic matrix; it presents exactly the same form and degree of convexity as in the genera *Didelphys* and *Dasyurus*. In its relative position to the series of molar teeth, with which it is on a level, it corresponds with *Dasyurus* more nearly than with *Didelphys*: in the *Dasyurus ursinus*, in fact, as well as in the allied marsupial genus, *Thylacinus*, the condyle has precisely the same relative position to the molar series; so that this particular structure in the jaw of the *Phascolotherium* affords no argument against its admission into the *marsupial series*.

The general form and proportions of the coronoid process (*b.*) resemble those in the zoophagous Marsupials; but in the depth and form of the entering notch, between this process and the condyle, it corresponds most closely with the *Thylacinus*.

It is, indeed, a most interesting fact, that this rare and solitary genus, represented by a single species (the Hyæna of the Tasmanian colonists), whose term of existence seems fast waning to its close, should afford the only example of a form and backward extension of the coronoid process, and a corresponding deep emargination above the condyle, which would else exclusively characterize the ancient *Phascolotherium*†.

* Von Leonard and Bronn's Neues Jahrbuch, 1835, s. 186.

† Mr. Broderip, in his description above alluded to, observes, "that it may not be uninteresting to note, that a recent species of *Trigonia* has very lately been discovered on the coast of Australia, that

The base of the inwardly-bent angle of the lower jaw progressively increases in *Didelphys*, *Dasyurus* and *Thylacinus*; and, judging from the fractured surface of the corresponding part in the fossil, it also resembles most nearly, in this respect, the *Thylacinus*.

The condyle of the jaw is nearer the plane of the inferior margin of the ramus in the Thylacine than in the Dasyures or Opossums; and consequently, when the inflected angle is broken off, the curve of the line continued from the condyle along the lower margin of the jaw in the Thylacine is least: in this particular again the Phascolothere resembles the Thylacine. In the position of the dental foramen, the Phascolothere, like the Thylacothere, differs from all the zoophagous Marsupials already cited, and also from the placental *Feræ*; but in the *Potoroo* (*Hypsiprymnus*), a marsupial Herbivore, the orifice of the dental canal is situated, as in the Stonesfield Marsupials, very near the vertical line, dropped from the last molar tooth. (See letter *e*, Pl. V. figs. 1, 2 and 3, and Pl. VI. figs. 1 and 2.)

A portion of the inner wall of the jaw, near its anterior margin, in the Phascolothere, has been violently broken off, so that the form of the symphysis cannot be precisely determined; but in the gentle curve by which the lower margin of the jaw is continued along the line of the symphysis to the anterior extremity of the jaw, the *Phascolotherium* resembles *Didelphys* more than *Dasyurus* or *Thylacinus*.

It is interesting to find that this analogy is associated with a correspondence in the condition of the teeth at the anterior part of the jaw. In examining the fossil we can scarcely refuse our assent to Mr. Broderip's opinion, that there were originally four incisors in each ramus of the jaw of *Phascolotherium*, as in *Didelphys*. Of the three incisors which are actually present in the fossil, only the internal and posterior surfaces are displayed, and not the whole breadth of the tooth; so that in the enlarged figure of the jaw detached from its matrix, the incisors appear both narrower and further apart than they really are. The incisors in the *Thylacinus* are of a prismatic form; and the surface, corresponding to that which is exposed on the fossil, forms one of the angles, from which the tooth increases in breadth to its anterior part, which forms one of the three facets.

Allowing for this circumstance, which must be borne in mind in an endeavour to arrive at the true affinities of the Phascolothere, the incisors in that fossil are

land of Marsupial animals. Our specimen," continues Mr. Broderip, "lies imbedded with a number of fossil shells of that genus. The individuals are of the same species so frequently found at Stonesfield." —*Loc. cit.* p. 4. May we be permitted to conjecture that Australia, in its marsupial inhabitants, its *Araucariæ* and Cycadeous plants, with the living *Clavagellæ*, *Terebratulæ* and *Trigoniæ* of its coasts, presents us with the picture, as it were, of the last remains of an old and worn-out world,—of one that has long been superseded in this hemisphere by other strata and a higher type of mammiferous organization?

evidently separated by wider intervals than in *Thylacinus*, *Dasyurus* or *Didelphys*; and the Phascolothere resembles, in this respect, as in the smaller proportions of its canine, the genus *Myrmecobius*.

In the proportions of the grinders to each other, especially the small size of the hindmost molar, the Phascolothere resembles the *Myrmecobius* more than it does the Opossum, the Dasyure or the Thylacine; but in the form of the crown it resembles the Thylacine more closely than any other genus of Marsupials. In the number of molar teeth the Phascolothere differs both from the Thylacothere and the *Myrmecobius*, and resembles the Opossum and Thylacine, having three false and four true molars, or seven grinders altogether, in each maxillary ramus. The distinction between the false and true molars is however much less strongly marked, both in the Phascolothere and Thylacine, than in the Opossum. The difference between the false and true molars in the Opossum is chiefly indicated by the addition, in the true molars, of a pointed tubercle on the inner side of the middle large tubercle, and in the same transverse line with it; but in the Phascolothere, as in the Thylacine, there is no corresponding tubercle on the inner side of the large, middle, pointed cusp; its place is occupied in the *Phascolotherium* by a ridge, which extends along the inner side of the base of the crown of the true molars, and projecting a little beyond both the anterior and posterior smaller cusps, gives the quinquecuspid appearance to the crown of the tooth, as represented by Dr. Buckland in his magnified view of the antepenultimate grinder of the *Phascolotherium*, given in the 2nd Plate of the illustrations of the Bridgewater Treatise. In the Thylacine the internal ridge is not continued across the base of the large middle cusp, but it extends along and beyond each of the lateral cusps, so as to give the tooth a similar quinquecuspid form to that which characterizes the true molars of the Phascolothere. Connecting the close resemblance which the molar teeth of the Phascolothere bear to those of the Thylacine with the similarities which have been already shown to exist in the several characteristic features of the ascending ramus of the jaw, I am of opinion that the marsupial extinct genus, indicated by the Stonesfield fossil here described, was nearly allied to *Thylacinus*, and that its position in the marsupial series is between *Thylacinus* and *Didelphys*.

There are two linear impressions on the inner side of the horizontal ramus of the jaw of the Phascolothere which have been mistaken for indications of *harmoniæ*, or toothless sutures, analogous to those which join together the component pieces of the compound jaws of reptiles and fishes. One of these is a faint, shallow, linear impression, continued from between the antepenultimate and penultimate molars, obliquely downwards and backwards, to the foramen for the dental artery. I conceive it to be due to an accidental crack; and if the portions of the bone

which it separates were to be compared to the contiguous margins of the opercular and dentary pieces of a reptile's jaw, it would be seen that the only suture, which in Reptiles is continued from any part of the level of the dental series between these pieces, passes in a totally different direction; it is the suture which bounds the anterior part of the opercular piece, and which, in all reptiles, runs obliquely downwards and forwards, instead of downwards and backwards. The second impression (*d.* fig. 2. Pl. VI.) in the jaw of the *Phascolotherium* is much more strongly marked than the preceding; it is a linear groove continued from the anterior extremity of the fractured base of the inflected angle obliquely downwards to the broken surface of the anterior part of the jaw. Whether this line be due to a vascular impression, or an accidental fracture, I do not offer an opinion; but this may be confidently affirmed, that there is not any suture in the compound jaw of a reptile which occupies a corresponding situation. And lastly, with reference to the philosophy of pronouncing judgement on the saurian nature of the Stonesfield fossils from the appearances of sutures in the jaws themselves, I would offer one remark, the justness of which will be obvious alike to those who are and those who are not conversant with the details of Comparative Anatomy.

The cumulative evidence of the true nature of the Stonesfield fossils, afforded by the shape of the condyle, coronoid process, angle of the jaw, different kinds of teeth, with the shape of their crowns, double fangs, and implantation in sockets, reposes on structures which cannot be due to accident, while those which favour the evidence of the compound structure of the jaw *may arise* from accidental circumstances.

The dental formula of the genus *Phascolotherium* is as follows:—

Incisors $3\frac{?}{-3}$; canines $\frac{?}{1-1}$; premolars $\frac{?}{3-3}$; molars $\frac{?}{4-4}$.

IV.—*A Letter from* Dr. Harlan, *addressed to the President, on the Discovery of the Remains of the* Basilosaurus *or* Zeuglodon.

[Read January 9, 1839.]

Mr. President,

WITH your permission, and at the request of several Members, I offer a few observations on the fossil bones from the United States now on the table.

In the early part of the year 1832 a large fossil vertebra was presented to the American Philosophical Society by Judge Bree of Louisiana, found in the "marly" banks of the Washita river, Arkansas territory. We then ventured to consider it as the vertebra of a large extinct Saurian of a nondescript genus, and proposed to name it provisionally *Basilosaurus*; the matrix contained a species of fossil *Corbula*, common in the Alabama tertiary deposits;—these remarks were not published until 1834. In the autumn of the same year a box of similar bones was received from the Hon. Mr. Creagh, from his plantation in Alabama, containing several enormous vertebræ, an *os humeri*, portions of the jaws and teeth, and some other fragments, supposed to belong to the same animal. Specimens of *Nautilus*, *Scutella*, and *Modiolus*, of extinct and new species, together with some fossil Shark's teeth, were obtained at the same time, from a similar rock in the vicinity. The great disparity in the proportional size of the different bones, which are all destitute of animal matter, presents a remarkable feature in the structure of this animal; so much so indeed, that we were at first disposed to refer the large and small vertebræ to different species; and one rib, obtained at the same time, is evidently that of a fossil *Manatus*. Bearing in view the form and structure of the teeth only, we should have been inclined to have ranked the animal amongst the marine Carnivora, however unlike those organs in any known species; but a careful examination of the other portions of the skeleton, especially of the lower jaw, which is elongated and hollow, appeared to forbid this arrangement, and to characterize it as a lost genus of the saurian order. The immense size and proportions of the vertebræ, and the total length of the vertebral column in the two skeletons—the one noticed at Alabama, the other at Arkansas—being estimated,

one at 100 feet, the other 150 feet in length,—the peculiar structure of the ribs, the form and size of the humerus, all differ widely from those parts in any of the known species of the Cetacea. I nevertheless take pleasure in acknowledging that the accurate and laborious investigations, and intelligent observations, made by my friend Mr. Owen on these fossils, during the several days they remained with him at the Royal College of Surgeons, have thrown new light on their structure and analogy. The remarks which we hope to elicit from him on the present occasion, with the means he possesses to verify them, will no doubt enable the Members to arrive at some final conclusions as to the true position which the animal under discussion ought to occupy in the animal kingdom.

I believe no one doubts that it is generically distinct, at least, from anything fossil or recent hitherto discovered.

I must now be indulged in a few observations on another extinct fossil animal, which has occupied much attention. It is the portion of the snout of a Saurian, said to be upwards of seventy feet in length, the head being only three or four feet long. It was discovered some eight or ten years since by a beaver-trapper, on or near the banks of the Yellowstone river, in the territory of Missouri, imbedded in a hard blue limestone rock. On my first examination of this specimen, I was under the impression, that it belonged to the genus *Ichthyosaurus*, though differing very materially from any species hitherto described; the structure of the teeth, mode of dentition, and the position of the anterior nares, led to this analogy; but the separate alveoli, and the form and position of the intermaxillary bones, separate it from this genus.

On my return from Europe in 1833, the memoir on this animal, which I had offered through the Transactions of the American Philosophical Society, was just passing the press; I had therefore only time to add the following note:—

"Since writing the foregoing essay, the author has enjoyed a more extensive field of observation, in the numerous and magnificent collections of Europe, and has satisfied himself, that the 'Missouri fossil' must be considered as an extinct fossil and altogether new, characterized, more particularly in the fragment in question, by the extreme length, breadth, and projection of the intermaxillary bone, in which it presents a marked difference from any of the genus *Ichthyosaurus*, and approaches the Batrachian order." (*Vide* Transactions of the American Philosophical Society, 1833; and Medical and Physical Researches, p. 148.) As the name under which this animal was originally described, must be changed, I propose to designate it as the *Batrachiosaurus Missouriensis.*

R. HARLAN.

London, January 9, 1839.

V.—*Observations on the* Basilosaurus *of* Dr. Harlan (*Zeuglodon cetoides*, Owen).

By RICHARD OWEN, Esq., F.G.S., F.R.S.

[Read January 9, 1839.]

Plates VII., VIII., and IX.

In the recent discussion on the Stonesfield fossil jaws, one of the arguments adduced in support of the Saurian hypothesis of these jaws was founded on the presumed existence of a reptile possessing teeth with double fangs, this reptile being the *Basilosaurus* of Dr. Harlan*. I refused to admit the validity of this argument until the teeth had been subjected to a re-examination, with an especial view to their alleged mode of implantation, and I adduced as reasons for my objection, the instance of the *Megatherium*, in which the highest authority in Comparative Anatomy had been deceived in regard to this very point of structure. (See ante, p. 61.) But the appeal to the *Basilosaurus* had rendered it desirable to determine, not only the actual mode of implantation, but also the general conditions of the teeth of that interesting and problematical fossil, and I felt more especially desirous to apply to them a test founded on the microscopic examination of their intimate structure, which in many other cases I had found to afford very satisfactory and unexpected results. The arrival of Dr. Harlan in this country with some of the remains of the extinct animal in question, and the permission which he has liberally granted me of having the sections of his valuable fossils made which I required, have enabled me, much sooner than I could possibly have hoped, to arrive at such conclusions, as to the nature of the *Basilosaurus*, as can be safely founded on the dental characters ascertainable by this mode of investigation; and I now, in compliance with Dr. Harlan's request, proceed to recount the details of this examination.

The parts of the *Basilosaurus*, relating to the present subject, brought over by Dr. Harlan, and now on the table, are two portions of bone belonging to the upper jaw; the larger one containing three teeth (Pl. VII.), the smaller one the sockets of two others.

The crowns of the teeth in the larger portion are more or less perfect, and are contiguous to each other; but they are placed rather obliquely, so that the inner surface

* Medical and Physical Researches, 8vo, 1835, pp. 337, 349.

of the anterior part of the crown of the hinder tooth is on the same line as the outer surface of the posterior part of the tooth next in front. They are compressed and conical, with an obtuse apex: the longitudinal diameter of the middle one (*b.*) is three inches, the transverse diameter of the same is one inch two lines; the height above the alveolar process two inches and a half. The crown is contracted in the middle, so as to give its transverse section somewhat of the hour-glass form* (Pl. VIII. fig. 1); and the opposite wide longitudinal grooves, which produce this form, become deeper as the crown approaches the socket, and at length meet, and divide the root of the tooth into two separate fangs: this fact, which was not clearly demonstrated in the original fossil, is proved by the transverse sections below the crown of one of the teeth (Pl. VIII. fig. 2). The anterior tooth (Pl. VII. *a.*) is somewhat smaller than the posterior ones, and presents also a more simple structure. The vertical groove is deeper in the two posterior teeth, and, in the hindmost (*c.*), which is much broken, it gives the appearance of two distinct simple teeth. Besides the teeth implanted in the jaws as above described, there is a fragment of a tooth imbedded in the matrix containing the above pieces, and consisting of the base of the crown and beginning of the fangs. The crown of this tooth, which is equal in size to the posterior one in place, and was probably a tooth of the same jaw, is partly worn down and partly broken, but is so blended with the matrix, that its exact form could not be determined. Of this tooth I had a transverse section made near to the base of the crown, which presents the figure represented in Pl. VIII. fig. 1, and is that form which we may reasonably suppose would be characteristic of the old and worn-down teeth of the *Zeuglodon.* The crown is divided into two irregular rounded portions or lobes, placed one before the other, and joined by a narrow neck or isthmus. The anterior lobe is the broadest, its grinding surface is subovate, and placed obliquely; it measures one inch, three lines in the long diameter, one inch in the short diameter; the posterior lobe is narrower, more regularly ovate with the long diameter (which is one inch, three lines), placed parallel with the axis of the jaw. The isthmus is about three lines in breadth and two in length; but the breadth diminishes while the length increases as the tooth descends in the socket, until it finally disappears, and the two portions take on the character of separate fangs. It is evident that the pulp which, from the form and structure of the crown, was originally simple, has soon become divided into two parts, and that its calcification has proceeded towards two distinct centres, which are each separately surrounded by concentric striæ of growth, the exterior of which sends an acute-angled process into the isthmus uniting the two portions. The *cavitas pulpi*, which is very small in the crown

* The term *Zeuglodon* (Ζευγλη, a yoke, *οδους*, a tooth,) which I have substituted for that of *Basilosaurus*, is expressive of this form of the teeth, which resembles two simple teeth linked or yoked together.

of the tooth, becomes contracted as the fangs descend, and is almost obliterated near their extremities, proving that the pulp of the teeth once calcified is not renewed, so that their growth is limited.

In a fractured anterior portion of the hindmost tooth, the pulp-cavity is seen to widen as the tooth descends in the jaw; it is not, however, surrounded, as in the section above-described, by concentric striæ, but enlarges towards that side next the posterior portion of the tooth, as if it were continuous with the enlarged pulp-cavity of that portion; from this appearance it is evident that the growth of this tooth was less advanced than the preceding, as might be expected from its position in the jaw. The sockets in the anterior fragment of the upper jaw were filled with the hard calcareous matrix, and their condition and extent were but obscurely seen: the first is described as being the socket of *a double molar*, i. e. of a molar with two distinct fangs, and the two corresponding cavities are so represented in Dr. Harlan's work*. To remove all doubt upon this point, I have caused to be made a transverse horizontal section of the alveolar margin, which shows clearly that the sockets of both the absent teeth are single, and that they had single fangs. In the anterior one there is an indication of the transverse median contraction of the tooth, which shows that this tooth resembled in form, to a certain degree, the posterior tooth. The longest diameter of this socket is two inches, four lines, the shortest one inch. The other socket is of a more simple form, viz. elliptical, measuring one inch, five lines, by eleven lines; it appears to have originally lodged a tooth further displaced from the jaw. The interspace between these teeth is one inch, five lines; the interspace between the second tooth and the one behind it, one inch, ten lines.

Of the fragment of the lower jaw of the *Zeuglodon* there is a plaster-cast in the Society's Museum. It contains four teeth, of which the two posterior are nearly contiguous; the next is separated from them by an interval of an inch and a half, and the most anterior is placed at a distance of two inches from the preceding. The anterior tooth is here of smaller size and apparently of more simple form than those behind, and it is described by Dr. Harlan as a canine. This interesting fragment is preserved in the Museum of the Philadelphian Academy; it confirms the evidence afforded by the fragments of the upper jaw, viz. that the teeth in the Basilosaur were of two kinds, the anterior being smaller, more simple in form and more remote from each other, than those behind.

Now the animals which have teeth lodged in distinct alveoli, and with which therefore we have to compare the *Zeuglodon*, are certain fishes, as the *Sphyræna* and its congeners; certain reptiles, as the plesiosauroid and crocodilian Sauria,

* *Loc. cit.* (Fig. 1. B.C. Pl. XXVI.).

and the class Mammalia. As there is no known instance of either fish or reptile having its teeth implanted by two fangs in a double socket, I shall proceed in the first place to compare the above-described general and obvious characters of the teeth of the *Zeuglodon* with those of the Mammalia which most nearly resemble them in these respects; and then point out more particularly the discrepancies which, in a similar comparison, are observable in the teeth of Reptiles.

In the true or zoophagous Cetacea, the teeth in each species resemble one another in form and structure, and are invariably implanted by a broad and simple basis in the socket, and never have two fangs. This uniformity and simplicity of structure does not, however, prevail in the herbivorous section of the cetaceous order, but the species differ considerably both as to the structure, form, number, and mode of implantation of the teeth. In the Manatee the molars have two long and separate fangs lodged in deep sockets; and the anterior teeth, when worn down, present a form of the crown somewhat similar to that of the *Zeuglodon*, but broader, and with the opposite indentations less deeply penetrating the crown of the tooth (Pl. VIII. fig. 4). These teeth however, when entire, present a form of the grinding surface very different from those of the *Zeuglodon*, inasmuch as it supports two transverse conical ridges; while the hinder molars differ still more, in having three transverse ridges.

The Dugong presents a nearer general resemblance to the *Zeuglodon* in its molar teeth, the anterior ones being smaller and more simple than the posterior, and the complication of the latter being due to exactly the same kind of modification as in the hinder teeth of the *Zeuglodon*. The posterior molar has its longitudinal diameter increased, and its transverse section also gives an approach to the hourglass figure, in consequence of the tooth being traversed longitudinally by two grooves, which encroach upon the substance of the tooth from opposite sides (Pl. VIII. fig. 3); there is also in this tooth a tendency to the formation of a double fang, and the establishment of two centres of radiation for the calcigerous tubes of the ivory; yet the molar teeth are not separated by wide intervals, as in the *Zeuglodon*.

In the scattered position of the teeth and their general size, we have an equivalent to the extinct *Zeuglodon* in the Cachalot; but the teeth in this Cetacean, besides being almost confined to the lower jaw, are, as before stated, simple and with single fangs.

After a comparison of the teeth of the *Zeuglodon* or Basilosaur with those of the true Saurians, I cannot find that they possess any one of the known dental peculiarities of that class. For first, besides their implantation in the jaw by double-fangs, they differ from the teeth of all known Saurians in their more complex and various forms.

They differ from those of the great *Mosasaurus* and all the Lacertian Reptiles, in being freely implanted in sockets, and not anchylosed to the substance of the jaws.

They differ from the teeth of the *Ichthyosaurus* in being implanted in distinct sockets, and not fixed in a common and continuous groove.

There remain then only the *Plesiosaurus*, *Megalosaurus*, *Thecodonsaurus*, and the Crocodilian reptiles with which to compare the teeth of the *Zeuglodon*. Now in these higher reptiles, which have the teeth implanted in distinct sockets, the part of the tooth so inserted is always single, and maintains, as it descends, a broad base, which is hollow. But in the *Zeuglodon*, on the contrary, the two fangs diminish in size as they sink in the socket, and become consolidated by the progressive calcification of a temporary pulp. In all Saurians, moreover, there are one or more new or successional teeth in different stages of formation, situated close to, or contained in the cavity of the base of the protruded tooth; but no trace whatever of this characteristic Saurian structure has yet been detected in the jaws of the *Zeuglodon*.

If, therefore, I had had to give an opinion on the nature and affinities of the *Zeuglodon* from the obvious external characters alone of its teeth, I should have concluded from these characters that it was no Reptile, but a mammiferous animal, most probably belonging to the cetaceous order, and more nearly allied to the herbivorous than to the piscivorous sections of that order as it now stands in the Cuvierian System.

As, however, the so-called Basilosaur has been regarded by some able anatomists as affording an exceptional example among the Reptilia of teeth having two fangs, contrary, indeed, to all analogy, so in like manner they may prefer to consider the facts above-cited, relating to the solidification of the fangs and the absence of numerous successional teeth, as exceptional dental conditions in an extinct Saurian form, rather than as evidence of the mammiferous nature of the fossil in question: I have therefore proceeded to investigate the intimate structure of the dental substance in the *Basilosaurus*, with a view to ascertain whether the evidence thus afforded would be contradictory to the previous inferences of its mammiferous nature, or give cumulative proofs of their correctness.

I may premise, that the teeth of the *Sphyræna* and allied fossil fishes, which are implanted in sockets, are distinctly characterized by a continuation of medullary or pulp canals, arranged in a beautifully reticulate manner, extending through the entire substance of the tooth, and affording innumerable centres of radiation to extremely fine calcigerous tubes.

In the Enaliosaurs and Crocodiles, the pulp-cavity of the tooth, which is analogous to the subdivided medullary canals in the sphyrenoid fishes, is simple and

central, as in the Mammalia. The calcigerous *tubuli* radiate from this centre to every pa.t of the circumference of the tooth, to which they are generally placed at right angles*. The whole of the 'dentine,' or ivory of the tooth, is composed of these minute tubules and their connecting tissue; but that part of the dentine which forms the crown is covered with enamel, while that part which is placed in the alveolus is surrounded with a thick layer of cortical substance, filling up the grooves of the fluted base of the tooth.

In the Dolphins, which have simple conical teeth like the higher reptiles, the inserted base is likewise covered with cæmentum, but the crown with enamel.

In the teeth of the Cachalot there is no true enamel, but the whole exterior is invested with a thick layer of cæmentum, which is sometimes as thick as the included portion of true tubular ivory.

In the Dugong, also, both the exposed and inserted parts of the molar teeth are coated with cæmentum, and this substitute for enamel presents the same characteristic radiated corpuscles or cells as were discovered by Purkinjé in the cæmentum of the human teeth, and of other animals; but the cæmentum of the Dugong differs from that of the Pachyderms and Ruminants in being traversed by numerous fine tubes, pretty closely aggregated, and giving off numerous branches, the corpuscles or cells being scattered in the interspaces of the tubes, which here and there communicate with the true calcigerous tubes of the ivory. Now the crowns of the teeth of the *Zeuglodon* evidently exhibit in many parts an investment of a thin layer of a substance distinct from the body or ivory of the tooth, the real nature of which investment microscopic examination could alone determine.

In a fine section of this part of the tooth of the *Basilosaurus*, taken from about the middle of the exposed crown, I find that this investment is cæmentum and not enamel, and that it presents the same microscopic characters as the cæment of the crown of the teeth of the Dugong. The Purkinjean cells are scattered in some places irregularly, in others arranged in parallel rows; they are about $\frac{1}{250}$th of a line in diameter, generally of an oval form, but with very irregular outlines: the tubes radiating from the cells are wider than usual at their commencement, but soon divide and subdivide, forming rich reticulations on the interspaces, and communicating with the branches of the parallel larger tubes. These are placed, as in the Dugong, perpendicularly to the superficies of the tooth, but are less regularly arranged than the calcigerous tubes of the ivory, with which, however, they form numerous continuations. There is a greater proportion of the cæmentum at the isthmus of the tooth than elsewhere.

The entire substance of the ivory of the tooth consists of fine calcigerous tubes,

* The general direction of the calcigerous tubes is indicated by the fine white lines in figs 1 and 2, Pl. VIII.

radiating in the section examined from two centres, one in each lobe, without any intermixture of coarser medullary tubes, such as characterize the teeth of the *Iguanodon*, and without the slightest trace of the reticulate canals which distinguish the texture of the teeth of the Shark, the *Sphyræna* and its congeners.

The breadth of the calcigerous tubes in the *Zeuglodon* is equal to one-eighth of the diameter of an ordinary human blood-disk or globule; they present a regular undulating course, and, like the calcigerous tubes of the Dugong, exhibit more plainly the primary dichotomous bifurcations, and the subordinate lateral branches, which are given off at acute angles.

Upon the whole, the microscopic characters of the texture of the teeth of the *Zeuglodon* are strictly of a mammiferous character, and the nature of their investing substance limits the comparison of these teeth with those of the few Mammalia in which the teeth are devoid of enamel. Among these are the Edentata, including the *Megatherium* and its congeners, the Morse, the Dugong and the Cachalot. The tooth of the *Megatherium* contains two kinds of dentine; the first is a coarse central portion with large medullary canals, giving off the short calcigerous tubes which occupy the interspaces of the canals, similar to the substance which composes the entire tooth of the *Orycteropus*; and the second is a fine and dense dentine, composed of minute parallel calcigerous tubes. The cæmentum of the *Megatherium* is also distinguishable by the large medullary canals which traverse it, and which anastomose by loops close to the true or dense ivory. We have therefore sufficient evidence that the *Zeuglodon* is not a gigantic edentate Mammal.

From the *Toxodon* it differs in the fangs of its teeth, and also in the fact that the teeth of the *Toxodon* are partially covered with true enamel.

It is to the teeth of the Cachalot and Dugong that those of the Basilosaur offer the nearest resemblance in the particulars already cited, and I conceive its position in the natural system to have been in the cetaceous order, intermediate between the Cachalot and the herbivorous species.

Dr. Harlan, who has examined with me the sections of the various teeth above alluded to, and who is willing to admit the arguments deducible from them in favour of the mammiferous nature of the Basilosaur, has himself suggested the propriety of substituting another generic name more in accordance with the true affinities of the animal, and has consented that the gigantic monarch, as it was deemed, of the saurian race, should be deposed*.

* The fragments of jaw and teeth, humerus, and fragments of rib, were discovered in a limestone rock, supposed to belong to a formation more recent than the Maestricht beds, in the Alabama territory. The vertebræ of the *Zeuglodon* were discovered by Judge Bree in a tertiary stratum, associated with conglomerate masses of small marine shells, principally belonging to an extinct species of *Corbula*; they were imbedded in a hill about two hundred yards from the Owachita or Washita river, Arkansas territory, in the state of Louisiana. The circumstances which led to their discovery are thus described:—

The idea, indeed, that the *Zeuglodon* was a reptile was not suggested by an examination of the teeth, but of the vertebræ, of which the most entire specimen is now on the table, being the original from which Dr. Harlan's figure is taken, and respecting which M. Duméril* has already expressed his opinion, that it presents the characters rather of a cetaceous than a saurian animal (Pl. VIII. fig. 6).

This vertebra most resembles, in fact, the anterior caudal vertebræ of the *Hyperoodon.* The most characteristic proof of its cetaceous nature is afforded by the traces of the original separation and subsequent union of the epiphyseal laminar pieces constituting the anterior and posterior articulating surfaces of the body, while the actual union of these plates indicates a tendency to a higher mammiferous character; the same epiphyses, for example, become anchylosed to the bodies of the vertebræ in the herbivorous Cetacea as in the mammiferous quadrupeds.

In the bodies of the smaller vertebræ of the *Zeuglodon*, however, the articular epiphyses are wanting; and Dr. Harlan himself infers, from the common occurrence of this condition, that there were originally three separate points of ossification in the body of the vertebra†. It is the persistence of this structure, which does not exist in any Saurian, that forms the most prominent character of the vertebræ of the Cetacea. It is to the presence of the two depressions or perforations in the lower part of the body of the vertebræ, and to the supposition that this structure peculiarly characterized the *Plesiosaurus*, that the belief of the saurian character of the *Zeuglodon* is mainly attributable; but the fact that this structure is present in the vertebræ of many Mammalia, and especially of the Whales, entirely invalidates the inference.

The vertebræ of most Sauria exhibit the articular depressions for the superior arch, which, from the want of more intimate union with the body, is generally lost in fossil vertebræ; but in the large vertebra of the Basilosaur we have clear proof

"After the occurrence of a long spell of rainy weather, a part of the hill slid down near to the water's edge, and thereby exposed twenty-eight of these bones, which had been until then covered by an incumbent mass of earth about forty feet thick. When these bones were first seen they extended in a line, which, from what the person living near the place showed me, comprised a curve, measuring upwards of 400 feet in length, with intervals which were vacant. The person referred to destroyed many of the bones by employing them instead of andirons in his fire-place, and I saved what remained from the same fate. I think, however, that a great many more bones belonging to the same animal are yet covered, and will gradually appear as the soil and marl shall be washed off by the rain."—*Extract from a letter from Mr. H. Bree in Dr. Harlan's Medical and Physical Researches*, 8°, 1835, p. 337.

* Compte Rendu des Séances de l'Académie des Sciences, Oct. 22, 1838. Dr. Buckland gave a similar opinion on the vertebræ of the *Basilosaurus* on the occasion of the discussion of the affinities of the *Thylacotherium*, November 21, 1838.

† *Loc. cit.* p. 356.

that the superior arch was continuous with the body of the vertebræ, as is always the case in the mature Mammalia.

Another argument for the mammiferous and cetaceous character of the *Zeuglodon* may be drawn from the great capacity of the canal for the spinal chord, which, in the Cetacea, is surrounded by an unusually thick plexiform stratum of both arteries and veins. The cetaceous character is further manifested in the short antero-posterior extent of the neurapophyses, as compared with that of the body of the vertebra, in their regular concave posterior margin, and the development of the articular apophyses only from their anterior part.

In one of the caudal vertebræ of the *Hyperoodon*, which measured $8\frac{1}{2}$ inches in length and $4\frac{3}{4}$ inches in height, the base of the superior arch was four inches in longitudinal extent, and occupied the same relative position as in the *Zeuglodon*. In the short-tailed Plesiosaurs the bodies of the vertebræ are always shorter in proportion to their breadth, and the superior arch springs from nearly the whole length of their upper surface, and they have no anchylosed transverse processes. In the Crocodile, where these processes are present, they are situated higher up on the body of the vertebræ. In those vertebræ of the Cetacea, with which I have compared the vertebra of the *Zeuglodon*, the transverse processes have the same relative position, but they are more depressed. The *Zeuglodon*, therefore, in this respect again shows a tendency to the higher mammiferous character; the transverse processes of the caudal vertebræ of the Manatee and Dugong are relatively thicker than in the carnivorous Cetacea. Lastly, I may observe that the articular surfaces of the body of this vertebra of the *Zeuglodon*, besides both being more uniformly convex than in any saurian vertebræ which I have seen, also present the strongly-marked concentric striæ which characterize the flat or slightly convex articular surfaces of the Mammalia.

With respect to the other bones of the *Zeuglodon*, I may observe that the fragments of the ribs present a thick, expanded form and dense texture, which strikingly resemble the ribs of the Manatee, and clearly bespeak an aquatic Mammal; but the excentric laminated structure of these bones, which Dr. Harlan has well described and figured, is peculiar, and unlike any structure which I have yet observed in the ribs of either Mammal or Saurian, and it resembles most the texture of the petro-tympanic bone of the Cetacea (Pl. VIII. fig. 5).

One of the fragments of the ribs is decisive also against the supposed affinity of the *Zeuglodon* to the Plesiosaur, since it presents an articular surface on the tubercle as well as on the head of the rib.

The hollow structure of the lower jaw has been adduced as evidence of the

saurian nature of the *Zeuglodon*, but it stands equally good for its cetaceous character, as a section of the lower jaw of the Cachalot demonstrates.

In the compressed shaft of the humerus (Pl. IX.) and its proportion to the vertebra, the *Zeuglodon* approximates to the true Cetacea, as much as it recedes from the Enaliosauria; but in the expansion of the distal extremity and in the form of the articular surface, the humerus of the *Zeuglodon* stands alone. No one can contemplate the comparative feebleness of this, the principal bone of the anterior extremity, without feeling the justice of Dr. Harlan's conclusion, that the tail must have been the main organ of locomotion of this stupendous denizen of the deep. But assuming the humerus to have been part of the same skeleton with the vertebra, and that this bone truly indicates the power and application of the vertebral column of the *Zeuglodon*, can we suppose this flexible region of the spine to have been encumbered with a sacrum and pelvis and hinder extremities?

To this conclusion we must arrive if we admit the correctness of Dr. Harlan's determination of the bone which he has described and figured as the tibia. Now in this bone, which is fortunately among the portions of the *Zeuglodon* brought over by Dr. Harlan, the enlarged end, called distal, is fractured, so that no part of the articulating surface remains; and the projections, called internal and external malleolus*, are the results of accidental fracture.

The texture of the bone is laminated and dense like the ribs. The whole fragment presents a much less compressed form than we should expect to find in one of the long bones of the arm or leg of a marine Mammal or Saurian, and it seems to be a more probable conjecture, that it is a portion of one of the larger anterior ribs than a bone of a hinder extremity.

In recapitulating the chief points of evidence which, at present, can be brought to bear on the question of the affinities of the *Zeuglodon* or *Basilosaurus*, it may be stated, that the form of the humerus, though unlike that of any known vertebrate animal, yet approaches much closer to the mammalian than to the saurian type; the vertebræ, which we have been enabled to examine, not only present a strictly mammalian organization, but also the cetaceous modification of that type. The teeth being of two kinds, some with single, others with double fangs,—being freely implanted in distinct sockets,—consisting only of dentine and cæment, and both these presenting an intimate structure most closely resembling that of the same

* Harlan, *loc. cit.* p. 358.

constituents of the teeth of certain aquatic Mammals, as the Dugong,—afford a body of evidence which is conclusive as to the class of Vertebrata to which the extinct animal has belonged, and point with a high degree of probability to the order and family to which it bore the closest affinities. But the organization of the *Zeuglodon*, so far as it is at present known, forbids any closer approximation with the types of existing species.

The teeth, in their combination of an exaggerated condition of the conjugate form,—which is but indicated in certain teeth of the Dugong, with two distinct fangs, in their oblique position in the jaw, and the irregular interspaces of their alveoli,—present very striking and singular peculiarities; and when to these dental characters we add the remarkable and abrupt contraction of the distal end of the humerus, which is nevertheless provided with an articulating surface for a ginglymoid joint, and its remarkably diminutive size,—a cetaceous character, which, likewise, is here carried to an extreme,—and when we also consider the dense laminated structure of the ribs, and the third exaggeration of a cetaceous structure in the extreme elongation of the body of the caudal vertebræ,—we cannot hesitate in pronouncing the colossal *Zeuglodon* to have been one of the most extraordinary of the Mammalia which the revolutions of the globe have blotted out of the number of existing beings.

VI.—*Description of a Tooth and Part of the Skeleton of the* Glyptodon clavipes, *a large Quadruped of the Edentate Order, to which belongs the Tesselated Bony Armour described and figured by Mr. Clift in the former Volume of the Transactions of the Geological Society; with a consideration of the question whether the* Megatherium *possessed an analogous Dermal Armour.*

By RICHARD OWEN, Esq., F.G.S., F.R.S.

[Read March 23rd, 1839.]

PLATES X. XI. XII. and XIII.

THE first notice of the discovery of the osseous remains of the skeleton of a large edentate Mammal associated with fragments of a tesselated bony armour, similar to that of the Armadillo, appears in the note appended to the end of Cuvier's chapter on the *Megatherium*, in the 4to edition of the *Ossemens Fossiles*, published in 1823.

This notice occurs in an extract from a Letter addressed by D. Damasio Larranaga, Curé of Monte Video, to M. Auguste St. Hilaire. The facts stated in this extract are the following:—A femur was discovered in the Rio del Sauce, branche du Saulis-Grande, which weighed seven pounds; it was short, but might be from six to eight inches in width; it resembled in every respect the femur of an Armadillo; with it was found a portion of tesselated bony armour, of which the Curé promises to send one of the component pieces (une de ces écailles) to M. Auguste Geoffroi. The tail was very short and very stout (très-grosse); it had, in like manner, a bony armour (des écussons), but this was not verticillate, or disposed in rings. These fossils are stated to have been met with near the surface of the earth, in alluvium, or strata of transport, indicative of a very recent epoch; similar fossils are said to occur in analogous strata near the lake Mirim, on the frontier of the Portuguese colonies.

The notion that the fossils here mentioned belonged to the *Megatherium* rests solely on the circumstance of the worthy Curé having inserted the word *Megatherium* as the synonym of his gigantic *Dasypus*: "Je ne vous écris point sur mon *Dasypus* (*Mégathérium*, Cuv.), parceque je me propose d'en faire l'objet d'un mé-

moire," &c. *loc. cit.* p. 191. The admeasurement which he fortunately gives of the femur proves that if that bone really belonged to the *Megatherium* it must have been part of a very young animal; for whereas the femur of the *Megatherium* is sixteen inches in width, that of the fossil in question has at the utmost only half that width. Without laying much stress on the accuracy of Don Larranaga's comparison of his fossil femur with that of the existing Armadillos, I may observe that the femur of an Armadillo presents a striking character, in the third trochanter, likely to catch the eye of the most superficial observer; and that if the fossil femur in question did actually present this character, it would be decisive against its identity with that of the *Megatherium.*

Cuvier, however, makes no comment on these discrepancies, but merely observes that the Curé's letter announces or indicates that the *Megatherium* had pushed its analogies with the Armadillos so far, as to be covered like them with a scaly cuirass.

The next observations bearing upon the present question occur in Prof. Weiss's Geological memoir on the Provinces of S. Pedro do Sul and the Banda Oriental*, where certain fossils, collected by the Prussian traveller Sellow in the state of Monte Video, are described.

One of these fossils is the fractured distal end of the femur of the *Megatherium*; it had been discovered by the Indians, or at least made use of by them in cooking their food, in the neighbourhood of the Queguay, one of the tributaries of the Uruguay, and was found by Sellow near one of their deserted encampments: the fragment belongs to the right femur; the outer condyle is knocked off, and the bone is said to be blackened by fire. In short, it had been put to precisely the same use as that to which the vertebræ of Sir Woodbine Parish's *Megatherium* were applied by the Peons who discovered that skeleton. No mention is made of any armour or portions of armour having been discovered associated with or near to this fragment; but in the ford of the Queguay a Spanish soldier found a fossil, which passed into the hands of the Surgeon major, Francisco Meves, and by him was given to Sellow. This fossil is figured in Pl. IV. of Professor Weiss's memoir; he conjectures that it may have formed part of the tail-armour of the *Megatherium*, but allows that it is a fossil of very dubious character. It is unquestionably a portion of the dermal bony armour of some loricated animal.

Sellow also collected, in the neighbourhood of the Queguay, portions of a fossil carapace, undoubtedly belonging to a large Tortoise, and to which the name of *Testudo Sellowii* is given by Weiss†.

The portions of tesselated bony armour, figured by Professor Weiss, Pl. I. and II., and described at p. 277 of his Memoir, were obtained by Sellow on the Arapeychico, in the province of Monte Video; but no bones, either of the *Mega-*

* Abhandlungen der Kon. Acad. der Wissenschaften zu Berlin; 1827.

† *Loc. cit.* p. 286, Pl. V.

therium or any other animal, are mentioned as having been associated with them. This fossil armour precisely corresponds with that discovered at the lake Las Averias, and brought over to England by Sir Woodbine Parish, and of which a portion is figured by Mr. Clift in his memoir on the *Megatherium**.

A third series of fossils, in which fortunately some bones of the extremities were discovered associated with the tesselated bony case, was presented to Sellow by the President of the province of San Pedro, with the information that they had been originally discovered in the proximity of the Rio Janeiro. Now these important bones are not described by Professor Weiss; but he states that they will form the subject of a subsequent memoir by Sellow himself. Prof. Weiss, however, gives the dimensions of the pieces of the armour, which, as the bones found therewith belonged chiefly to the left fore-leg, he conjectures to have belonged to the anterior and inferior part of the left side of the carapace. The chord of the longitudinal curve of the longest fragment measured twenty-three inches, and the depth from the middle of the chord to the under-surface of the concavity was two and a quarter inches. The chord of the transverse bow or curvature was ten inches, and the depth from the middle of the chord to the under surface of the armour four inches; from which Sellow conjectured that the animal must have been ten feet, or fifteen palmas long, by seven palmas broad and four and a half palmas high.

Thus the fossils from South America, noticed in the Berlin memoir, resolve themselves into three distinct groups, from three different localities; first, a bone without armour; secondly, armour without bones; and thirdly, armour and bones mingled together in the same bed.

Now the portions of tesselated armour from the two localities, viz. Arapeychico and Rio Janeiro, are identical in structure. Professor Weiss's opinion, that they belong to the *Megatherium*, rests solely on the observation made by Cuvier in reference to the note of the Spanish Curé, the bearing of which on the present question we have already examined; it is obvious, therefore, that the bones, found with the armour, can alone yield us the information we are in quest of, as to the nature of the huge animal so singularly protected. Fortunately for science, and for the determination more especially of the present interesting question, these bones have been excellently described and illustrated by Professor D'Alton†, to whom they were confided for that purpose after the decease of Sellow. They include the fractured extremity of the humerus, the entire radius and ulna, and a great proportion of the fore-foot, all belonging, as stated by Weiss, to the left side, and a less complete series of bones of the left hind-foot. Not any teeth, or portions of the skull accompanied them to Berlin, so that Professor D'Alton restricts his

* Geological Transactions, 1835, p. 438.

† Abhandlungen der Kon. Acad. der Wissenschaften zu Berlin; 1833.

general conclusions respecting them to the facts that they are not remains of the *Megatherium*, but of a large edentate species more nearly allied to *Dasypus*.

Professor D'Alton, at the conclusion of his memoir, alludes to the notice in the Proceedings of the Geological Society of London of the discovery of three skeletons of *Megatherium* in the province of Buenos Ayres, of which two were associated with the bony armour. This notice refers to the collection of fossils sent to this country by Sir Woodbine Parish ; I need scarcely observe, however, that of the three skeletons alluded to, only one is referrible to the *Megatherium*, and the parts of this skeleton which were brought to England have been described by Mr. Clift in the memoir already alluded to. No trace of an ossified dermal covering was found with or near this skeleton. Of the other two skeletons which were associated with the bony armour, portions of the armour alone, without bones, of the one, and a few bones without armour of the other, were brought to England ;—the latter bones are described in the present paper.

The skeleton to which they belonged was discovered at Villanueva, in the bed of a small rivulet, but the greater part of the bones crumbled to pieces on exposure to the air. The only portions which it was possible to preserve were the extremity of a jaw with three alveoli ; part of the scapula, the distal end of the left humerus, the left radius, nearly entire ; two unguial phalanges of the fore-foot; the distal end of the left tibia and fibula, anchylosed together ; the left astragalus, calcaneum, naviculare, cuboides, and external cuneiform bones, including the three middle unguial phalanges of the hind-foot. The shell is described by Sir Woodbine Parish as having been situated about a foot below the principal mass of the bones, the concave side uppermost, and resembling the section of a large cask ; it would not, however, bear lifting out of its bed, but broke into small pieces, and crumbled into dust almost immediately.

The small portion of the skeleton which was brought to England was presented by Sir Woodbine Parish to the College of Surgeons*, together with the magnificent remains of the true *Megatherium*. Casts of the bones were made by order of the College, and presented, together with casts of the bones of the *Megatherium*, to different Museums, and amongst the rest to that in the Jardin du Roi at Paris. These casts attracted the attention of M. Laurillard, and Mr. Pentland, who was at that time at Paris. M. Laurillard has alluded to them in the following note appended to the chapter on the *Megatherium* in the lately published 8vo Edition (1836) of the *Ossemens Fossiles*. After giving the letter of the Curé Larranaga and Cuvier's comment on it, Laurillard says, " Il serait fort possible que le *Mégathérium* fut en effet récouvert de cuirasses écailleuses ; cependant il ne faudrait pas se hâter

* These fossils are here described and figured, agreeably with the conditions of their presentation, by permission of the Museum Committee of the Royal College of Surgeons.

de lui attribuer les grands fragmens qu'on a trouvés, car les plâtres envoyés de Londres démontrent qu'un Tatou de taille gigantesque existe, avec le *Mégathérium*, dans les plaines de Buenos Ayres. Ces morceaux caractéristiques consistent dans un calcaneum, un astragale et un scaphoid qui ne s'éloignent de ceux des Tatous vivans que par la grandeur et par des différences purement spécifiques *."

Mr. Pentland at the same time assured Sir Woodbine Parish, in a letter of the date of December 1835, that the bones which were found associated with the armour at Villanueva did not belong to the *Megatherium*, but to a gigantic Armadillo; this opinion he arrived at by comparing the tarsal bones above-mentioned with those of the *Dasypus gigas*.

There is no question but that the correspondency, above indicated by MM. Laurillard and Pentland, in the structure of three of the most characteristic of the tarsal bones, sufficiently indicates the general affinity of the extinct animal possessing them to the Armadillo family; but I shall hereafter show that the modifications of the other bones of the foot are such as to indicate something more than a specific distinction. Besides, it was evident both to Mr. Clift and myself, at the time when we first examined the fragment of the jaw accompanying these bones, that the conformation of the alveoli in that fragment indicated a dentition differing more widely from that of the existing sub-genera of Armadillos than their respective dental characters differ from one another; we, therefore, hesitated in assigning these fossils to the genus *Dasypus*, hoping soon to obtain further information as to the dental character of the species to which they belonged.

It was at this conjuncture, that Sir Woodbine Parish received the intelligence of the discovery of an entire skeleton, covered with its tesselated coat of mail, about five feet below the surface, in the bank of a rivulet near the Rio Matanza, about twenty miles south of the city of Buenos Ayres; and with the account of this remarkable discovery there was, at the same time, transmitted a drawing or sketch of the whole animal, which has since been lithographed, and one of the teeth of the fossil itself (Pl. X. fig. 1 and 2). This tooth Sir Woodbine Parish obligingly submitted to my examination: its general structure proved it to belong to an animal referrible to the Edentata of Cuvier; but its form was so peculiar, that I had no hesitation in pronouncing it to differ from that of any known edentate animal, recent or fossil, and, from its intimate texture, to be indicative of a new sub-genus of the Armadillo family, for which I proposed the name of *Glyptodon*, in reference to the fluted or sculptured character of the tooth. A brief description of the tooth, with the account of the discoveries of the skeleton, were immediately printed, and have been published in Sir Woodbine Parish's work on Buenos Ayres†. Subsequently, the recollection of the fragment of the jaw, with its pecu-

* *Loc. cit.* tom. viii. p. 368.

† P. 178 *b*. Frontispiece, 8vo, 1838. Since the reading of the present paper, the discovery of bones

liar alveoli, occurred to me; and on comparing the tooth of the *Glyptodon* with that fragment, I have found that the largest socket in it agrees in size and form with the tooth, and that the longitudinal ridges, which characterize the socket and distinguish it from those of the existing Armadillos, precisely correspond with the peculiar flutings in the tooth itself.

Thus, then, the suspicion that the bones, discovered with the tesselated osseous coat of mail at Villanueva, might appertain to the same species as the more perfect skeleton and cuirass found near Rio Matanza, is converted into a certainty; and we may entertain hopes, that the materials will shortly arrive from which we may obtain as complete a knowledge of the osteology of the *Glyptodon*,—the true possessor of the hitherto-described tesselated armour,—as exists of the *Megatherium* itself.

The *Glyptodon* differs from the *Megatherium* not only in the form and structure, but in the number of its teeth, which appear, from the figure and account transmitted to Sir Woodbine Parish, to be eight on each side of each jaw, as in the section of Armadillos called *Cabassous* by Cuvier. Judging from the same sketch, the *Glyptodon* differs from all known Armadillos in the form of the lower jaw, and in the presence of a long process descending from the zygoma, in both which respects it resembles, and evidently indicates a transition to, the *Megatherium*. The same figure shows the tail to be more remarkable for its thickness than its length, and to be protected by armour covering only the upper surface like a roof, and not encompassing it like the verticillate caudal armour of the Armadillos, in both which respects we cannot fail to perceive a correspondence between the *Glyptodon* and the great *Dasypus* with armour, described as a *Megatherium* by the Curé Larranaga.

I shall refrain, however, from any further remarks or speculations which might be suggested by the figure and notice of the entire *Glyptodon*, published by Sir Woodbine Parish, and proceed to describe the portions of that animal which have actually reached this country.

The molar tooth (Pl. X. fig. 1 and 2) from the Rio Matanza is fractured, but the grinding surface, and upwards of an inch of the crown, are quite perfect. The whole length of this fragment is two inches and three lines, and there is no indication of a diminution in any of its diameters, from the grinding surface to the opposite fractured end: in this respect it agrees with the form of the sockets in the fragment of the jaw of the individual previously discovered, as these sockets terminate abruptly without any contraction: from their depth we may conclude that the length of the

and armour of the *Glyptodon*, under the name of *Hoplophorus*, by M. Lund, in the caverns of the valley of the Rio das Velhas, Brazil, has been announced in a letter from that gentleman to M. Victor Audouin, published in the *Comptes Rendus*, Avril 15, 1839. Prof. D'Alton has subsequently brought the subject of the *Glyptodon* before the meeting of the German Naturalists at Erlangen, September 1839, and has proposed for it the generic name of *Pachypus*.

entire tooth was about four inches; the antero-posterior diameter of the tooth is one inch; the transverse diameter varies from six to seven lines. The three sockets in the fragment of the jaw give the same general proportions, though they vary a little as to size, whence it is shown that the teeth of the *Glyptodon* are much more compressed than those of the *Megatherium*; they differ still more materially in their intimate structure, which corresponds with that of the Armadillos: the main body of the tooth, or the dentine, consists of fine calcigerous tubuli, radiating with a pretty straight course from the medullary cavity; the dentine is surrounded by a very thin layer of cæmentum, and the pulp-cavity, at the upper part of the tooth, is consolidated by the ossified remains of the pulp, which is harder than the surrounding dentine. The teeth of the *Glyptodon*, however, differ in a marked degree from those of all the known species of Armadillo, in being traversed, through the whole length of both their outer and inner sides, by two broad and deep angular grooves, each extending from the opposite sides about one-third of the transverse diameter of the tooth, so as to divide the grinding surface into three portions, joined together by the contracted isthmus interposed between the opposite grooves. Of these portions the posterior one is broader than the other two. The sockets present longitudinal angular ridges, corresponding to these channels or flutings, and prove that they were continued through the whole length of the tooth; this is slightly curved, and the concavity is turned inwards in the teeth of the lower jaw, as in the *Toxodon*. I have elsewhere observed that the teeth of the *Glyptodon* exhibit a more complicated form than those of any recent or extinct edentate species hitherto discovered, and seem to indicate a transition from the Edentata to the pachydermatous *Toxodon*: it will be hereafter seen that the modifications of the locomotive extremities bespeak a similar tendency in the *Glyptodon* to the multungulate Pachyderms.

The fragment of the jaw of the *Glyptodon*, discovered at Villanueva with the other bones now about to be described, consists of a portion broken off from near the extremity of the left ramus, and includes three alveoli, which slightly increase in size as they are placed farther back; this circumstance, as well as the anterior position of the sockets, correspond with the sketch of the entire *Glyptodon*, already published by Sir W. Parish, and make us regard with more confidence the indications of an affinity to the *Megatherium* in the double flexure of the lower jaw, and the long descending process from the zygoma represented in that sketch. As the general correspondence of the conformation of the alveoli with the structure of the teeth has already been noticed, it is only necessary to subjoin their dimensions. The antero-posterior diameter of the first is ten lines; the transverse diameter of its posterior division, which corresponds to the broadest part of the tooth, is five lines; the antero-posterior diameter of the second socket twelve lines; its transverse diameter six lines and a half; the antero-posterior diameter of the third

socket thirteen lines ; its transverse diameter cannot be determined, the inner wall of the socket being broken away.

Humerus.—The distal half of the left humerus exhibits a thick projection beyond the internal condyle, and a broad, thin, and well-produced supinator ridge above the external condyle, which, with the articular trochlea for the antibrachial bones, are closely conformable with the structure of the humerus in the Armadillos ; but the internal condyle is not perforated, and the depressions above the trochlea, both in front, and more especially that behind, are relatively deeper. The twist of the humerus is strongly marked; the base of the strong deltoid trochanter is discernible at the fractured extremity of the bone; but on the opposite side there is a rugged raised surface for a muscular insertion, of which I do not perceive the analogue in the Armadillos. The humerus of the *Megatherium*, notwithstanding it apparently offers the same exception among Edentata with that of the *Glyptodon* in the imperforation of the internal condyle, differs widely from the present bone in the extraordinary expansion of its distal extremity, especially of the external condyle.

Radius.—The radius of the *Glyptodon*, in its comparative shortness and general form, likewise corresponds very closely with that of the Armadillos ; it differs principally in being less compressed. The proximal, semioval, articular surface, which plays upon the anterior part of the trochlea of the humerus, is, in the transverse direction, convex on the inner and concave on the outer side ; the inner part of the proximal end is much produced : the posterior surface of the bone is traversed longitudinally by a deep and wide rugged groove ; the bone assumes somewhat of a trihedral figure towards its distal end ; the anterior ridge is produced below the distal articulation in the form of an obtuse, sub-compressed process ; the posterior ridge terminates in a broad rugged process ; the radial, which in the prone position of the bone becomes the inner side of the distal extremity, is much produced ; the distal articular concavity is formed by an oblique excavation leading downwards from the posterior towards the anterior margin of the distal end ; the articular surface is divided by an oblique groove into two parts, and in some species of Armadillo this groove is represented by an entering notch.

The description and figure which Professor D'Alton has given of the radius, which forms one of the series of bones associated with the bony armour described by Professor Weiss, proves them to belong to a species of *Glyptodon* identical with the present : the characteristic process from the fore-part of the distal end of the radius appears, however, to be broken off in Sellow's specimen ; and the bone is about one-fourth smaller, belonging, as the separate epiphyses demonstrate, to an immature individual. The radius here described measures seven inches and a half in length, and three inches across its distal end.

The perfect radius of the *Megatherium*, forming part of the skeleton brought to this country by Sir Woodbine Parish, fortunately affords the means of a close com-

parison between it and the corresponding bone of the *Glyptodon.* It measures twenty-eight inches in length, and six inches and a half across its distal end.

Besides the disparity of size, which is most striking—the radius of the larger Edental being more than three times greater in every dimension,—we find well-marked differences in all the details of its conformation: its proximal articular surface is subcircular and uniformly concave; the margins of this concavity are not extended in any direction, so as to overhang any part of the shaft of the bone; this shaft is compressed, and the radial edge produced; the concave distal articular surface is nearly at right angles with the axis of the bone, and there is no process developed from its anterior part. The *Megatherium*, in deviating from the *Glyptodon* in all these points, deviates of course in the same degree from the Armadillo-tribe.

To judge from the figure which Professor D'Alton has given of the ulna of Sellow's *Glyptodon*, this bone equally illustrates the affinity of the latter animal to the Dasypodoid, and its deviation from the Megatherioid families of Edentata.

Two unguial phalanges, which, from their obliquity, had been referred by Mr. Clift to the fore-foot, are proved to be correctly so referred by the memoir of Professor D'Alton, in which the bones of nearly the entire fore-foot are excellently described and figured. The difference in size between the bones so figured and the present phalanges corresponds exactly with that which has been noticed in the radius of the two specimens; the smaller phalanx in the present collection belongs to the third, the larger to the fourth toe, of the left fore-foot. In both, the proximal extremity offers a double shallow articular pulley; it is placed obliquely, so that the end of the bone must have been inclined somewhat downwards. The upper and outer margin is produced; the bone is thicker on the inner than the outer side, towards which it slightly bends; the upper surface is evenly convex, but pitted with numerous vascular impressions, which are strongest at the margin; the under surface of the phalanx presents a rough, convex protuberance, occupying the posterior half of the under surface.

Of all Edentata, existing or extinct, the species of the genus *Dasypus* are those to which the *Glyptodon* makes the nearest approach in the structure of the unguial phalanges; but in their shortness, as compared with their breadth and depth, these bones of the *Glyptodon* resemble still more the unguial phalanges of the Pachyderms: the middle and proximal phalanges of the fore-foot of the *Glyptodon*, which are described and figured in the memoir of Prof. D'Alton, differ from those of both the Armadillos and the Pachyderms in their very remarkable shortness, and in the flatness of their articular surfaces. The short, broad, depressed terminal phalanges of the *Glyptodon* must have been encased in correspondingly short and strong hoof-like claws, and have presented a striking contrast with the foot of the

Megatherium. The long and compressed claw-bone of this gigantic Edental, with its basis encompassed by a bony unguial sheath, bespeaks the fore-foot to have been an instrument, the use of which, in scratching and digging, and perhaps occasionally defending its possessor, were of more consequence in the living economy of the individual, than mere subserviency to support and progression. The peculiarly compact and robust structure of the foot of the *Glyptodon,* on the other hand, is eminently suggestive of such a subserviency, and more especially as the base of a column of support; but as this fore-foot was associated with a rotatory condition of the radius, it is probable that the *Glyptodon* had the power of applying its anterior extremities to all the purposes to which the Armadillos, its nearest congeners, apply theirs.

Of the posterior extremities, Sir Woodbine Parish's collection of the bones of the *Glyptodon* include the anchylosed distal extremities of the tibia and fibula; an astragalus, calcaneum, scaphoides, cuboides, external cuneiform bone, the three phalanges of the second toe and the middle and distal phalanges of the third and fourth toes, with a few sesamoid bones; all belonging to the left side*.

Sellow's collection also included most of these bones, but in a less perfect condition than the present. Both collections, while they establish the identity of the species possessing the ponderous bony covering, at the same time prove the close correspondence which subsists between the fore- and hind-feet of the *Glyptodon* in general form and structure.

Tibia.—Sufficient of the tibia remains to show that it had the compressed form and excavated inner surface characteristic of that of the Armadillos; that a similar wide space separated it from the fibula, with which it is also anchylosed; and that the anterior margin of the bone was continued obliquely as a strong ridge to the inner angle of the distal surface. The distal articular surface presents two concavities separated by a convexity, the outer hollow being the largest and deepest; the external malleolus forms a well-marked process, as in the Armadillos; at the back part of the tibia we find also two well-marked tendinous grooves separated by a projecting ridge. The corresponding part of the skeleton of the *Megatherium* deviates widely in the proportions of the tibia and fibula, and in the conformation of the distal articular surface from that of the *Glyptodon.*

Astragalus.—The upper surface of this bone (Pl. XI. fig. 3) describes a regular convex curve in the antero-posterior direction; transversely it forms, as in the Armadillo, two marginal convex trochleæ, separated by an intermediate wide concavity: the internal or tibial trochlea is somewhat lower and broader than in *Dasypus,* in which respects *Glyptodon* manifests an approximation to *Scelidotherium*†, which, in the structure of its astragalus, presents an intermediate step in

* Pl. X. fig. 3. † Fossil Mammalia of the Voyage of the Beagle, 4to, Pl. XXVI. figs. 2, 4 and 6.

the gradation from the Armadillo to the Sloth. In the astragalus of the *Glyptodon* a rough surface encroaches in the form of a concave notch upon the anterior margin of the tibial articular surface, as in the *Dasypus gigas*: the astragalus, anterior to this part, is extended forwards in the form of a rough convex protuberance, which overhangs the scaphoid articular surface (Pl. XI. fig. 4, *a*); the aspect of this articular surface is obliquely downwards and forwards, so that the whole of it is visible when we look upon the inferior surface of the astragalus: in the antero-posterior direction the scaphoid articular surface is nearly flat, very slightly concave anteriorly, and as slightly convex posteriorly; in the transverse direction it is regularly convex. Such a structure and disposition of the scaphoid articulation does not exist in any Armadillo; and the deviation on the part of *Glyptodon* from *Dasypus* in this respect is greater than any of the specific differences observable in the several *Dasypi*. The peculiar transverse extension of the articular surface for the scaphoid is well shown when the astragalus of the *Glyptodon* is viewed from the inner or tibial side, as in fig. 5, where this surface, surmounted by the tuberosity above described, is directed towards the right hand. The tibial articular surface encroaches only a slight way upon this side of the astragalus. The outer or fibular surface of the astragalus presents, in *Glyptodon*, a remarkably regular triangular figure, of which the upper and longest side is slightly convex, while the two lower sides are straight and equal; the fibular articular surface encroaches about half-way down this surface, but further posteriorly than anteriorly: the reverse of this is seen in the Armadillos, the astragalus of which also never presents this triangular form. The astragalus, indeed, of the Scelidothere, which in other respects more nearly resembles that of the Megathere, resembles that of the Armadillos in the form and condition of its outer facet more than does the astragalus of the *Glyptodon*. On the inferior surface of the astragalus of *Glyptodon* we perceive that the internal facet for the articulation with the calcaneum (Pl. XI. fig. 4, *b*) is separated by a rough groove, as in the Armadillos, from the scaphoid articular surface (*a*). In the Armadillos, however, the inner calcaneal surface is flat, or slightly convex; in the *Glyptodon* it is remarkably concave in the antero-posterior direction. The outer calcaneal facet (*ib.* fig. 4, *c*) is almost perfectly flat in *Glyptodon*; it is concave in all the Armadillos: both these differences may be regarded as something more than merely specific.

*Os calcis**.—In the calcaneum we of course perceive a corresponding difference between *Glyptodon* and *Dasypus*; the inner articular surface being flat in the former and convex in the latter, while the outer articular surface presents the reverse conditions. The inner surface of the posterior projecting part of the calcaneum is more concave in *Glyptodon* than in *Dasypus*; the under surface is broader and

* Pl. XIII. figs. 4 and 5.

flatter, and the posterior surface is produced in the form of a strong ridge below its level. The anterior articular surface for the os cuboides is relatively smaller than in the Armadillos; it is flat instead of concave, with the lower part bent forwards at an open angle with the vertical part of the surface: there is a much greater extent of rough surface on the anterior part of the calcaneum, below the cuboidal facet, than exists in the Armadillos; with these differences, however, the os calcis of the *Glyptodon* presents a much closer correspondence to that of the Armadillos than to that of the *Megatherium.*

*Scaphoides**.—I have already spoken of the peculiar aspect of the scaphoidal articular surface in the astragalus of the *Glyptodon*: the verticality of the articular surfaces upon the scaphoid bone for the cuneiform bones is produced by the great thickening of the lower part of the scaphoid as compared with the upper, which thus compensates for the obliquity of the articular surface on the astragalus. The scaphoid bone of the *Glyptodon* presents a remarkably compressed form; the posterior articular surface (Pl. XI. fig. 1, *a*) is concave, chiefly in the transverse direction, and corresponds in size and form with the opposed surface on the astragalus; a rough flattened margin, of about half an inch in breadth, intervenes between the posterior and anterior vertical articular surfaces, at their upper and outer parts. The tibial side of the scaphoid is produced and thickened, and is irregularly rounded; a very peculiar elongated conical and slightly twisted process (*ib. b*) is continued from the middle of the inferior thickened margin; the base of this process is separated by a smooth notch from the internal protuberance. The articular surface for the external cuneiform bone (*ib.* fig. 2, *c*) is the largest of the three and of a semilunar figure; the middle articular surface (*ib. d*) is in the form of a narrow vertical ellipse; the internal surface (*ib. e*) looks inwards and forwards, as in the Armadillos: external to the cuneiform articular surfaces there is a small narrow vertical facet for a part of the os cuboides.

Notwithstanding the peculiarities which have been pointed out, the scaphoides of the *Glyptodon* resembles that of the Armadillos much more than it does that of the Megathere, from which it differs more especially in the uniform concavity of the posterior articular surface.

The *external cuneiform bone* of the *Glyptodon*† differs from that of the different species of *Dasypus* in its remarkably compressed form; it is, in fact, a simple triangular plate of bone, with the posterior surface smooth and very slightly concave for the articulation with the scaphoid; the anterior surface very slightly convex for the articulation with the metatarsal of the third toe: the outer contour of the bone is convex, the inner one concave; the anterior articular surface encroaches a little on this side to join a portion of the metatarsal of the second toe: on the

* Pl. XI. figs. 1 and 2.

† Pl. X. fig. 3, *cn.*

under and outer side of the bone there is a very small facet, which touches the cuboides. The external cuneiform bone of the Megathere differs from that of the *Glyptodon* in being thicker as well as broader at its upper part; but, upon the whole, the external cuneiform bone of the *Glyptodon* resembles that of the Megathere more than it does that of the Armadillos.

The *os cuboides* of the *Glyptodon** deviates still more than the scaphoid bone from its analogue in the Armadillos in its remarkable antero-posterior compression: it presents an irregular oblong figure, thicker at its inner than its outer margin; the posterior surface presents a small convex articular surface for that of the os calcis, like which, the curve of the lower part is slightly angular; this surface is near the upper and outer margin of the bone; on the inner margin there is a long, narrow, sub-elliptic facet for the scaphoid. The inferior surface of the cuboid (Pl. XI. fig. 6) is divided by a deep and wide groove for the tendon of the peroneus muscle; above which is the triangular surface for the metatarsals of the two outer toes, which is bounded above by a rather sharp edge. The posterior part of the lower surface of the cuboid, like the adjoining part of the calcaneum, is smoothed down by the playing of the strong flexor tendons of the toes.

The middle and inner cuneiform bones are wanting; but it is evident from the space intervening between the second metatarsal bone and scaphoid, that they must have resembled the external cuneiform in their antero-posterior compressed shape.

The *metatarsals* of the three middle and largest toes† are fortunately preserved and entire; and here we have the most striking deviation from the existing Armadillos, in the extreme shortness of these bones, in none of which does the longitudinal or antero-posterior diameter equal either the transverse or vertical diameters.

The second metatarsal presents somewhat of a wedge-shape, broadest at its lower and inner sides, and narrowest at its upper and outer sides; posteriorly it presents a flat surface for articulating with the middle cuneiform bone, which articulation is two inches in vertical extent and an inch and a quarter across the upper part, and proves the middle cuneiform bone to have been much smaller than the external one above-described; this articular surface of the second metatarsal is continuous at its upper and outer angle with a small triangular facet, which articulates with the external cuneiform bone; a third oblong articular surface is continued from the preceding upon the greater part of a depression on the outer surface of the bone, and this articular surface is applied against a corresponding one on the upper and back part of the middle metatarsal. The articular surface on the anterior part of the bone for the first phalanx of the second toe is slightly convex, longer in the vertical than the transverse directions. At the under part of the bone are two trochlear surfaces for two sesamoid bones.

* Pl. X. fig. 3, *c b.*

† *Ibid, m, m, m.*

The third or middle metatarsal bone is the largest of the three; it diminishes in breadth, but greatly increases in antero-posterior thickness from the upper to the lower surface: the posterior articular surface is very slightly concave, and is nearly exclusively applied to the external cuneiform bone above-described: a small portion is deflected forwards from its upper and inner side to be applied to the oblique facet in the depression on the outer side of the second metatarsal: there is a similar depression and articular facet on the upper and outer side of the present metatarsal, in which a corresponding process of the fourth metatarsal is wedged. By this structure the three principal metatarsals are interlocked together, and any force or concussion from the toes would thus be transferred not only directly backwards to the tarsal bones, but obliquely from one metatarsal to another, whereby peculiar strength and security is given to the bony compages of the foot. The anterior surface of the middle metatarsal is slightly convex, two inches long by one and three quarters wide, which gives an idea of the bulk of the first phalanx of the middle toe: the under part of the present metatarsal bone presents two broad concave grooves for large sesamoid bones.

The fourth metatarsal is smaller than the second; its outer rough surface is convex, its inner one nearly straight, but with a small concave facet bounded by a raised ridge, and adapted to the convex articular surface in the depression on the opposed surface of the third metatarsal: the oblong posterior articular surface adapted to the os cuboides is slightly concave, with the transverse diameter equal to half the vertical one: the anterior surface for the fourth toe is triangular and nearly flat; there are two sesamoid grooves on the under part of this metatarsal bone. There are no remains of the small external or fifth toe, but its existence is indicated by a very small flat articular facet on the outer side of the fourth metatarsal bone, and by the extent of surface on the cuboid which it leaves uncovered. There is no evidence of the relative size of the first or innermost toe.

The three phalanges of the second, and the middle and distal phalanges of the third and fourth toes, are fortunately preserved. The proximal phalanx of the second toe* is a vertically oblong, compressed, plate of bone, thicker above than below in the antero-posterior direction; a protuberance rises from the middle and posterior part of the upper surface; the lower margin presents a deep and narrow notch. The posterior surface is slightly concave, the anterior one flat, with a rough spot in the centre. The second phalanx of the same toe† is still more compressed; its greatest length or antero-posterior extent, which is at the upper part, measures only six lines, whilst its vertical diameter is twenty lines, and its transverse diameter seventeen lines; its lower margin is notched like the preceding phalanx, and at the middle of the posterior articular surface there is a central

* Pl. XII. fig. 1, 1; fig. 2.

† *Ibid*, fig. 1, 2; fig. 3.

depression: from the very slight extent of motion allowed by these flattened articulations of the toes, one cannot be surprised that the synovial bag should be in part obliterated, as these rough places in the centre of the articulating surfaces would seem to indicate. The form of the anterior articulating surface of the second phalanx is shown in Pl. XII. fig. 3.

The distal or unguial phalanx of the second toe* presents a very remarkable form; it is suddenly expanded, in breadth and depth, immediately beyond the articular facet for the preceding phalanx, and this facet appears thus to occupy only the middle of the posterior surface, and to be surrounded by a broad rough margin. This surface is not placed at right angles to the long axis of the phalanx, but slopes from above downwards and forwards at a very acute angle with the upper surface, so that the apex of the phalanx points almost directly downwards; the inferior boundary of the posterior surface forms a rough ridge, separated by a smooth narrow concavity from the anterior border of the phalanx: the superior sloping surface is slightly convex, and deeply pitted and sculptured with vascular grooves and impressions.

The unguial phalanx of the third toe† is broader but shorter than the preceding, and is of a more symmetrical figure: the lower margin of its posterior surface forms a broader ridge, and the articular surface is a little more convex, but the resemblance is otherwise very close. The unguial phalanx of the fourth toe has the same general form as the preceding, but is smaller; like the last phalanx of the second toe, it is unsymmetrical, but from a different modification: in the second toe the inner margin is rounded off towards the outer; in the fourth toe the outer margin is rounded off towards the inner. The middle phalanx of the third‡ and fourth toes is more square-shaped and broader than that of the second; it has the same general compressed form, with nearly flat articular surfaces, but, being narrower above, it resembles an inverted wedge; it is also notched, but less deeply, below, and has an articular facet for a sesamoid bone on each side of the notch.

When the bones of the hinder extremity above-described are arranged in their natural relative positions, they present to our observation the framework of a foot of such a construction and form as I may venture to say is without a parallel in the animal kingdom: the nearest approach to its broad, thick, short, and massive proportions is made by the skeleton of the fossorial extremity of the Mole; but it is the fore-foot only of this animal that can be compared, in the compressed bulky figure of the metacarpals and proximal and middle phalanges, with the singular hinder extremity of the *Glyptodon* above-described. The hind-foot of the Mole resembles, in the lengthened metatarsal and phalangeal bones, that of the

* Pl. XII. fig. 1, 3; fig. 5. † *Ibid*, fig. 6. ‡ *Ibid*, fig. 4.

existing Armadillos, and the generality of quadrupeds. It might be conjectured, that the *Megatherium*, since its hind-foot is well known to be very apocryphally restored in the Madrid skeleton, may approximate in some degree in this part of its skeleton to the *Glyptodon*, especially if the hypothesis be admitted that the Megathere was in like manner laden with a ponderous coat of armour. But the structure of the terminal phalanges of the Megathere at all events differs most widely from that which we have just described in the *Glyptodon*: the compressed lengthened shape is as extreme in the claw-bones of the one, as the depressed shortened figure is in those of the other extinct quadruped. In the *Glyptodon* the foot appears to be expressly modified to form the base of a column destined to support an enormous superincumbent weight: in the *Megatherium* one would infer that the bulky body had not been clad in an expanded bony coat of mail, from the very circumstance that the toes were developed to sustain and wield long and compressed claws, such as form the compensating weapons of defence of the hair-clad Sloths and Anteaters. The unguial phalanges of the mailed Armadillos, in their shorter, broader, and flatter form, make a much nearer approach to those of the *Glyptodon*. We may readily admit, indeed, that the hind-foot of the *Glyptodon* is an extreme modification of the same general plan of structure as that on which the foot of the Armadillo is constructed; but if we were led to conclude that the differences in the tarsal bones exceeded those which were traceable in the same bones between one species of Armadillo and another, *à fortiori* we must admit that the antero-posterior compression of the metatarsals and phalanges, and the total suppression in these of the ginglymoid trochlear articulations in the *Glyptodon*, are indicative of a difference of general habits much greater than is usually observed in species of the same genus.

The dental modifications already described are conformable with, and in fact lead irresistibly to, the same opinion respecting the nature and affinities of the *Glyptodon*, as that to which we have been conducted by an examination and comparison of the locomotive organs: and it may be concluded, therefore, that the extinct edentate animal, to which belongs the fossil tesselated osseous armour described by Weiss, Buckland and Clift, cannot be called an Armadillo, without making use of an exaggerated expression, and still less a species of *Megatherium*; but that it offers the type of a distinct genus, which was much more nearly allied to the Dasypodoid than to the Megatherioid families of Edentata, and, most probably, connected that order of quadrupeds with the heavy-coated Rhinoceroses of the Pachydermatous group.

The question which may next arise, is, whether the tesselated armour described and figured by Prof. Weiss be specifically identical with that brought over by Sir Woodbine Parish, and described by Dr. Buckland and Mr. Clift. Their ex-

tremely close resemblance in point of structure will be manifest to whoever compares Plates I. and II. of Prof. Weiss's Memoir with Pl. XLVI. of Mr. Clift's paper: the polygonal pieces in the former are, however, generally a little smaller than those figured by Mr. Clift; yet some portions in Prof. Weiss's figures, as Pl. I. fig. 3, t. 1, fully equal in size the largest polygons in the English specimens, and the whole of his elaborate description tends to prove that the portions of armour discovered by Sellow and Sir Woodbine Parish belong to the same species of extinct animal. If, however, there were no other grounds for this opinion than the comparison of the coat of mail, we could not arrive at a perfectly satisfactory conclusion in consequence of the near resemblance which some species of Armadillo present in the structure of their tesselated armour; fortunately, however, the parts of the skeleton transmitted along with the armour by both Sellow and Sir Woodbine Parish, afford the means of arriving at positive certainty on this point. The radius and a few bones of the hind-foot of Sellow's specimen are sufficiently perfect, and their delineations by the highly-esteemed pencil of Prof. D'Alton are sufficiently characteristic and exact, to show them to be identical in form and structure with the corresponding bones of the *Glyptodon*, here described. Sellow's specimen was, however, as we have seen, a younger individual than Sir Woodbine Parish's, the epiphyses of the radius not being united, and the bone about one-fifth smaller. All the other bones of Sellow's specimen, which are sufficiently perfect to be compared with Sir Woodbine Parish's, show a corresponding inferiority of size, together with the other indications that the animal had perished ere it had attained its full growth.

Thus, then, we obtain proof that the only portions of tesselated armour transmitted to Europe, with the conditions requisite for determining the species to which they belonged, testify to their having formed part of the structure of an edentate animal, widely different from, and much smaller than, the *Megatherium.*

Does it therefore necessarily follow, it may then be asked, that the *Megatherium* was not in like manner covered with a bony coat of armour? Undoubtedly it does not. But the proof or the probability that it was so armed, must at present repose on arguments afforded either by modifications of the skeleton analogous to those which in the Armadillos have relation to their osseous coat of mail, or by other peculiarities indicative of a similar relation.

Our distinguished President, Dr. Buckland*, has called attention to the broad and rough flattened surface of a part of the crest of the widely-expanded ilium, to the breadth of the summit of the spines of many of the vertebræ, and also of the superior convex bend or angle of certain ribs, as affording "evidence of pressure

* Bridgewater Treatise, vol. i. pp. 160 and 161.

similar to that we find on the analogous parts of the skeleton of the Armadillo:" he has likewise adduced the massive proportions of the hind-legs and tail, as conditions consistent with the necessity for carrying so ponderous a cuirass as that which he supposes to have covered the body of the *Megatherium.*

But the above-cited modifications of the vertebræ, pelvis and ribs are more strongly marked in the skeleton of the Anteater and Sloth than in that of the Armadillo; and if the skeleton of this mailed Edental be studied in reference to its subserviency to the support of the dermal armour, the modifications for this end will be found to be widely different from, and more striking than, any which have been pointed out in the remains of the *Megatherium.*

The modifications of this nature which we observe in the pelvis of the Armadillo, are the following:—

1st. The anchylosis of a great number of vertebræ, so as to form a very long sacrum, which, in the *Dasypus tricinctus,* for example, includes twelve vertebræ*. 2ndly. The great antero-posterior development of the spines of these vertebræ, which thus form a continuous vertical ridge of bone, bearing immediately the superincumbent weight, and, in some species, as in the *Dasypus tricinctus,* by the corresponding development of a ridge from the median line of the under surface of the armour. 3rdly. This weight is transmitted from the sacrum to the thigh-bones by two converging bony columns on each side: one of these is formed by the ischium, which is anchylosed to the posterior part of the sacrum; the second and more characteristic mode of transferring the weight of the armour from the sacrum to the femur, is by the conversion of the iliac bone into a stout three-sided beam, passing straight from the thigh-joint to abut against the anterior part of the sacrum, where the weight of the shell is greatest. In no species of Armadillo is the ilium expanded; in some species a small angular process projects outwards from the sacral, or upper extremity of that columnar bone; in others, as the *D. tricinctus,* there is not even this feeble representative of the expanded ilia of the *Megatherium.* The *Megatherium,* in fact, resembles the Elephant in the size, form and position of its iliac bones, as well as in their expanded and flattened labrum, more nearly than it does any other existing quadruped. The Edentata which make the nearest approach to this characteristic structure of the Megathere are the Sloths, and next to them the great hairy Anteater (*Myrmecophaga jubata*). To argue that the broad and flattened ilia of the *Megatherium* are conditions of those bones by which they are adapted to sustain a heavy coat of bony armour, seems to imply that a continuous transverse wall would be a better support to a solid and unyielding roof than the judicious disposition of a less amount of material in the

* Pl. XIII. fig. 1. *c, c.*

form of beams. If a covering consist of flexible material, then the surface of support must be to a certain extent continuous or extended; and it would seem that it is on this principle that the iliac bones of the Elephant are arched outwards so as to afford an extended surface of support to its yielding, though dense, integument: we may therefore presume that a like relation subsisted between the expanded ilia of the *Megatherium* and its integument. The compact covering of the Armadillo rests upon a more contracted basis; and when we compare the mechanism of this support with the scaffolding of an inflexible roof, the same principle may be traced in both the natural and artificial architecture. It is by this chain of reasoning that I have been led to a conclusion, in respect of the relations of the iliac bones of the *Megatherium* to its integument, different from that which has been cited. But the part of the pelvic structure of the *Megatherium*, which, perhaps, tells the strongest against its possessing a ponderous coat of mail, is the paucity of the sacral vertebræ, conjoined with their structure. These, instead of being ten or twelve, do not exceed four in number, and they are further characterized by the comparatively small size of their spinous processes, which are not locked together as in the Armadillos, but are separated by intervals as in the Sloths.

It will be remembered that the estimable and justly celebrated author, from whose reasonings on the osteological relations of the *Megatherium* I have thus far ventured to dissent, enunciates his conclusion with philosophic caution, and states it to be probable that the *Megatherium* possessed a bony coat of mail.

But that which Cuvier and M. Laurillard have ventured to regard as only possible, and Dr. Buckland as probable, M. de Blainville has since announced to be a positive fact. He has communicated to the Academy of Sciences the statement that bones of the *Megatherium* have recently been discovered, accompanied with fragments of a carapace belonging indubitably to the same animal*; and he adds, that the association of a bony armour with the internal skeleton of the *Megatherium* can be demonstrated as surely by *à priori* reasoning as by the *à posteriori* fact.

Some interesting and novel arguments, deduced from the osteological structure of the *Megatherium*, might have been expected from so accomplished a Comparative Anatomist as the successor to Cuvier; but M. de Blainville restricts himself to the mere repetition of the conditions of the skeleton already argued upon by Dr. Buckland as indicating a probability that the sustaining of a heavy coat of mail was thereby provided for, affirming that the *Megatherium* is proved to be cer-

* "De nouvelles découverts d'ossemens de *Mégathérium* accompagné de fragmens de carapace, provenant indubitablement du même animal, outre celles d'ossemens d'autres espèces de Tatous," etc.—*Comptes Rendus*, 21re Janv. 1839, p. 57.

tainly covered with an osteodermal carapace, by the disposition of the spinous processes of the vertebræ, by the angles of the ribs, by the articulation of the pelvis with the vertebral column, etc.*.

Now pending the appearance of the description of the pieces of the carapace of the *Megatherium*, of which the discovery is announced by M. de Blainville, and the nature of which armour is as yet unknown to science, I may be permitted to offer a few observations, tending to show that the possession of such a carapace cannot be deduced by *à priori* reasoning, founded on the parts of the skeleton of the *Megatherium* cited by M. de Blainville. And in the first place I would observe, that in reasoning from the analogy of the Armadillos,—the only quadrupeds which possess a bony carapace,—we have the advantage of having presented to our observation a skeleton which presents throughout that family a constant and unvarying series of well-marked modifications in direct relation to such a carapace as the *Megatherium* is stated by M. de Blainville to possess.

Although I have cited the enormous sacrum, with its consolidated spines, and the buttress-like disposition of the strong columnar ilia, as among the modifications of the skeleton of the Armadillos which bear a physiological relation to their peculiar armour, these are by no means the most striking evidences of this relationship. What first catches the eye of the anatomist, in quest of these indications in the skeleton of the Armadillo, is the remarkable production of a process† of the vertebræ extending from above the anterior articular process on each side in an oblique direction upwards, outwards, and forwards to nearly the level of the extremity of the true spinous process‡: now these oblique processes, which are thus developed in no other quadrupeds, save the loricated Edentata, precisely and beautifully correspond in form and use with the tie-bearers in the architecture of a roof; but if we look deeper into the nature of the sustaining mechanism of the roof-like armour of the Armadillo, we shall find another purpose obtained by these processes, besides the office of the tie-bearer: the ordinary spinous process transmits the superincumbent weight simply to the vertebra from which it springs; the oblique processes transmit the weight partly to the vertebra to which they belong and partly to the vertebra next in front, because one half of their base or

* "Par l'ensemble de l'organization, comme par sa forme et par la carapace osteo-dermique dont il était certainement couvert, comme on peut aussi bien le prouver *à priori* qu'*à posteriori*, c'est à dire, par la *disposition des apophyses épineuses* des vertèbres, de *l'angle des côtes*, de *l'articulation de la ceinture osseuse postérieure* avec la colonne vertébrale, etc.; aussi bien que par Le Fait, c'était une espèce gigantesque de Tatou, plus voisin du Tatou chlamyphore que de tout autre, quoique celui-ci soit le plus petit du genre."—*Comptes Rendus*, 21re Janv. 1839, p. 68.

† Pl. XIII. figs. 1 and 2, *b*, *b*.

‡ *Ibid*, *a*, *a*.

origin is extended directly over the posterior oblique processes of the adjoining vertebra.

Now if we find so peculiar, so complicated, and so perfect a mechanical modification of the vertebral column of the Armadillo, relating immediately to the peculiar weight it is required to bear, we are surely justified in expecting a corresponding modification in the same part of the skeleton of the *Megatherium*, on the hypothesis that it had also to sustain armour corresponding with its enormous bulk. We look in vain, however, for these long oblique columnar apophyses in the vertebral column of the extinct giant; their analogues here maintain the ordinary condition of short transverse processes* directed outwards at right angles with the spinous process†; and the *Megatherium* in this respect corresponds with the hair-clad Sloths and Anteaters.

With respect to the ribs, I may observe that the armour of the Armadillo does not immediately rest on any part of these bones as it does on the vertebræ abovementioned: a stratum of muscular substance intervenes between the armour and ribs, and the latter are left free, and necessarily so, for the movements of respiration. The Sloths and Anteaters have broader and stronger ribs than the Armadillos; nay, they have relatively broader and stronger ribs than the *Megatherium* itself, and the angles of the ribs show the rough impressions of the insertions of the *levatores costarum* in the same relative degree as do the angles of the ribs of the Megathere, on which M. de Blainville supposes the carapace to have directly rested.

With respect to the relation of the bones of the extremities to a dermal armour, the difference of structure observable between the *Megatherium* on the one hand and the *Glyptodon* and *Dasypi* on the other, has already been pointed out. The columns supporting the trunk of the *Megatherium* are unquestionably of colossal proportions, but I conceive that the prodigious strength of the bones of the legs of the *Megatherium* was called for by the weight of the enormous superincumbent pelvis, which exceeds in the thickness and expanse of its several bones, relatively as well as absolutely, that of any other animal. And when to the weight of this ponderous cincture of bone, is added the mass of soft parts which must have encompassed and been lodged within it, I feel disposed to protest strongly against laying an additional load even upon the stalwart legs of the *Megatherium*.

But if the burthen of a bony coat of mail must needs be placed upon his heavy haunches, let us endeavour to form a true conception of its expanse. If we compare the average dimensions of the component tesseræ of the armour of existing Armadillos with their skeletons, we shall find that there is the same correspondence between the internal and external bones of these small cuirassiers, as between the endo- and the exo-skeleton of the *Glyptodon*.

* Pl. XIII. fig. 3, *b*, *b*.

† *Ibid*, *a*.

In the *Dasypus tricinctus*, for example, the radius, which measures one inch and four lines in length, is equal to the diameter of four of the marginal plates of the dermal covering. In the *Glyptodon*, the radius, which measures seven inches and a half in length, is equal to three and a half of the analogous dermal ossicles, which are, therefore, relatively larger than in the Armadillo.

But the bones of the skeleton of the *Glyptodon* which we have to compare with those of the *Megatherium* do not equal a third of the bulk of their analogues in the more gigantic Edental. If, therefore, the tesseræ of the coat of mail of the *Glyptodon* average a breadth of two inches, then those of the hypothetical armour of the *Megatherium* might reasonably be expected to present a proportional magnitude: and, from the abundance of the remains of the Megathere, and the vast number of tesseræ that must have entered into the formation of its expansive cuirass, hexagonal osseous plates of five or six inches diameter and proportional thickness, might be expected, if such a cuirass had really formed part of the enduring structures of the *Megatherium*, to have been found scattered more or less abundantly along the banks of almost every stream that flows through the Pampas; yet not a single piece of armour of a larger pattern than that of the *Glyptodon* has hitherto been discovered either in South or North America, where the bones of the *Megatherium* have occurred. And, finally, when we consider, that although parts of the armour of the *Glyptodon* have been discovered without bones, yet that its bones have never been found unassociated with more or less of the heavy covering in which it laid down and died, it must appear very improbable that, in every case in which the bones of the Megathere have been met with, its still heavier armour should have been entirely washed away.

The following is a tabular view of the principal circumstances connected with the discovery of twelve different skeletons of the *Megatherium*:—

No.	Date of discovery.	Where found.	By whom found.	Parts obtained.	Where deposited.
1.	1789.	R. Luxan, near Buenos Ayres.	Marquis of Loretto.	Nearly whole skeleton.	Royal Museum, Madrid.
2.	1795.	Lima.		Parts of skeleton.	ditto.
3.	ditto.	Paraguay.	Père Fernando Scio.	ditto.	ditto.
4.	1824.	Skidaway Marshes, New York.	Messrs. Mitchell & Cooper.	Teeth and few bones.	Lyceum, New York.
5.	1825.	White-bluff, Savannah.	Waring and Habersham.	Odd bones.	ditto.
6.	1826.	Queguay-Uruguay.	Sellow.	Part of femur.	Berlin.
7.	1833.	Rio Salado.	Sir Woodbine Parish.	Nearly entire skeleton.	Coll. Surg. London.
8.	1834.	North Patagonia.	Mr. Darwin.	Head.	ditto.
9.	ditto.	ditto.	ditto.	ditto.	ditto.
10.	ditto.	ditto.	ditto.	ditto.	ditto.
11.	1837.	Luxan, Buenos Ayres.	Signor Muniz.	Skeleton nearly entire.	Museum, Monte Video.
12.	1838.	Estancias de Rosas, Buen. Ayr.	Dr. Decalzi.	Various bones.	ditto.

In not one of these instances was any portion of bony armour discovered with or near the bones. For the knowledge of the two last-cited instances of the discovery of the *Megatherium*, I am indebted to Sir Woodbine Parish, who has also obligingly translated for me the following notice of the discovery of bones and armour of a fourth *Glyptodon* (assuming the Curé Larranaga's to have been the first), now deposited in the Museum at Monte Video. It forms the first of a list of fossils recently added to that Museum, and of which a brief notice occurs in a report on the subject inserted in one of the Spanish journals.

"*Account of Fossil Bones deposited in the Museum of* Monte Video, *and found in the year* 1838.

No. I.

"Fossil skeleton found in the left bank of the little river Pedernal before its junction with the Sala, an affluent of the Rio Santa, near Monte Video.

"After removing the earth about 27 inches from the surface, some portions of a *bony shell* or covering were discovered. These were composed of hexagonal divisions, 1 or 2 inches in diameter, varying in thickness from 1 to $1\frac{1}{2}$ inch. The thickest were attached to the dorsal region, and the thinner ones appeared to form the lateral extremities of the shield. From the centre of each of these polygons a small disc was noticed, of from $\frac{1}{2}$ to 1 inch in diameter, from which 6 or 8 lines diverge, leaving between them so many little quadrangular divisions. These pieces were joined by symphysis, and formed a sort of mosaic work, pretty symmetrical to the eye. The posterior part of the shell had a sort of border which probably bounded the coccygeal region, composed of more conical pieces than the rest, but of about the same diameter; (this caudal border formed a notch of 9 inches diameter). When first found, Don Roberto carefully measured the whole shell, which appeared like a huge barrel, and was 4 feet 9 inches over the transverse curve.

"On proceeding to remove the earth further, the first bones met with were two *lumbar* vertebræ, then one ilium, then that of the opposite side; lastly, the entire pelvis. The ilia and a large portion of the ischia of both sides were preserved. Some fragments saved very fragile.

"The vertebræ had subsided half a yard from the shell; they had spinous processes, and were united to the iliac bones, determining their separation. There was discovered also a wide bone, like the scapula (coracoid?) of a tortoise, adhering to the anterior part of the shell.

"A portion of a rib (5 inches long, 1 inch wide, at thickest part 10 lines). A phalanx (very hard, at least 1 inch long, 6 or 7 lines across middle part). Some shining fragments of a substance like that which covers the crown of certain molar teeth*. (Cranium and extremities searched for, but not found.)

"Every effort was made to get out the shell whole, but it mouldered away as soon as it was exposed to the sun and air.

"These Antediluvian remains were disposed in the Museum, to satisfy public curiosity."

---

* Afterwards described as some very lustrous fragments, some prismatic, and others slightly grooved (acanalados), of a colour like tortoise-shell, on which nitric acid effervesced strongly, as it did on the portions of the shield.

The following are some of the admeasurements of the above-described *Glyptodon* from the River Pedernal, and the admeasurements of the corresponding parts of the *Megatherium* :—

	Glyptodon.		*Megatherium.*	
	Inches.	Lines.	Inches.	Lines.
Width of pelvis from the anterior spine of one ilium to that of the other	22	6	61	
Total height of the vertebræ whose transverse processes separated the iliac bones	6	8	11	
Ditto of a spinous process	3	4	4	
Breadth of a vertebra at the base of its spinous process	3	1½	8	2
Height of the medullary canal		5	3	3
Width of ditto		3	4	2
Largest diameter of cotyloid cavity	5		8	
Least ditto of ditto	3	9	7	3
Depth of ditto	2	2	4	
The following are admeasurements of the bones of Sir Woodbine Parish's *Glyptodon*, and of the corresponding bones of the *Megatherium* :—				
Humerus, breadth of distal end	5	3	17	
Radius, length	7	6	28	
——— proximal circumference	6		12	3
——— middle ditto	4		11	6
——— distal ditto	7	8	19	
Tibia and fibula anchylosed, distal circumference	16		30	
Os calcis, length	6		18	
Astragalus, length	4	2	11	
Largest unguial phalanx, fore-foot, length	3		11	
——— breadth	1	10	3	
——— depth	1	8	6	

The description of the armour associated with the bones of the Pedernal *Glyptodon* proves it to correspond in size and structure with that of the *Glyptodon* of Villanueva; and the dimensions of the pelvis, which are one-third smaller than in the *Megatherium*, equally agree with those of the bones of the extremities of the *Glyptodon* at present in London.

The same Report on the Museum of Monte Video likewise contains a notice of the discovery, in the Banda Oriental, of pieces of armour, said to be identical with that found in the Pedernal. One of these pieces, which was associated with the caudal vertebræ, is thus described: "The covering of a tail was found in the Rio Seco, entire in its length, and composed of a single bony piece; but we observe in it portions similar to the plates of the before-mentioned shelly covering, but of more variable diameters.

This plate is hollow or excavated to its extremity, and presents in its concavity vestiges of caudal vertebræ very distant from one another.

"The exact dimensions of this tail, which is stated to resemble the tusk of an Elephant, are as follows:

	Inches.	Lines.
Length	19	0
Circumference at origin	13	6
Ditto middle	10	11
Ditto two inches from end	8	4
Thickness of the bony plate or roof	0	8

From the Banda Oriental."

This notice of the tail of the *Glyptodon* is very satisfactory, as it confirms the accuracy of the sketch of that discovered in the Rio Matanza, while both correspond with the distinctive character of the armour of the tail pointed out by the Curé Larranaga in the fossil Edental, which he calls both a *Dasypus* and a *Megatherium.*

We have thus evidence of the discovery of the remains of five individuals of a large edentate species, undoubtedly covered with armour, and more or less corresponding with the characters of the genus *Glyptodon*, which are deduced in the present paper from the structure of both dentary and locomotive organs.

That the portions of fossil dermal armour now in England, though exhibiting proportions which may be termed gigantic as compared with the osseous carapace of the Armadillos, belong, not to the *Megatherium*, but to the *Glyptodon*, cannot admit of doubt. It is always difficult, however, to establish a negative: but that the *Megatherium* possessed no analogous covering, will be also, I trust, conceded by those who may be willing to admit the validity of the arguments adduced at length in the foregoing pages, and which may be briefly summed up as follows:—

1st. The opinions of Cuvier and Weiss, in favour of the *Megatherium* being so armed, rest on no better ground than the mere fact of bony armour of some gigantic quadruped and the skeleton of the *Megatherium* having been discovered in the same continent.

2nd. The skeleton, or its parts which have been actually associated with the bony armour above mentioned, belongs to a different and smaller quadruped.

3rd. No part of the skeleton of the *Megatherium* presents those modifications which are related to the support of a bony dermal covering.

4th. The proportions of the component tesseræ of the bony armour in question to the skeleton of the *Glyptodon* are the same as those between the dermal tesseræ and skeleton of existing Armadillos, but are vastly smaller as compared with the bones of the *Megatherium.*

5th. No bony armour composed of tesseræ having the same relative size to the bones of the skeleton of the *Megatherium* as in the *Glyptodon* and existing Armadillos, has yet been discovered.

6th. The skeleton of the *Megatherium* has never been found associated with bony armour of any kind; neither have its parts been found so associated.

VII.—*On the Geology of the Neighbourhood of Lisbon.*

By DANIEL SHARPE, Esq., F.G.S.

[Read January 9 and 23, 1839.]

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PRELIMINARY REMARKS.

IN 1832 I laid before the Geological Society a few remarks on the strata in the neighbourhood of Lisbon; but having since spent some time in that city, I have been able to extend my observations and to correct the errors into which I had before fallen. During the latter part of my stay, I had the advantage of becoming acquainted with the Baron d'Eschwege, the author of a paper upon part of the district, in the eleventh volume of the Memoirs of the Royal Academy of Sciences of Lisbon, to whom I am indebted for much valuable information.

In the present paper my former remarks are repeated only as far as is necessary to render the rest intelligible. I shall first describe the aqueous formations, fol-

lowing the descending order, both in the general arrangement of the subject and in the tables of beds and description of sections ; and then the igneous rocks, with the disturbances which the sedimentary deposits have undergone. A few remarks on the great earthquake of 1755 are given as an appendix.

PART I.—Aqueous Deposits.

Tertiary Formations.

The tertiary beds appear to be entirely of marine origin, and they may be divided into three formations :

1. Upper Tertiary Sand.
2. Almada Beds; consisting of calcareous sands, sandy limestones, marls and clays. They may be best observed in the cliffs on the south bank of the Tagus, near the village of Almada.
3. Lower Tertiary Conglomerate.

These deposits occupy a basin, of which only a part is included in the region described in this paper. Their greatest extent is from the mouth of the Tagus to Abrantes, a distance of about eighty English miles ; and from Lisbon to Alcacer do Sal, about fifty miles. The Tagus runs through this basin from Abrantes to the sea, keeping close to its northern boundary, so that a very small portion of it lies north of the river.

1. *Upper Tertiary Sand.* (Pl. XIV. and Pl. XV., Sect. 1, 9, 11 to 13.)

This formation consists of about 100 feet of fine grey quartzose sand and 150 feet of coarse, quartzose, ferruginous sand and gravel.

On the south of the Tagus it covers nearly the whole of the tertiary district. Its beds are quite horizontal, except where they rest upon the inclined strata of the Almada formation towards the edges of the basin, and even there, the dip never exceeds ten degrees : I did not notice a single instance of their having been dislocated.

Baron d'Eschwege pointed out to me a very remarkable rock on the banks of the Sado, half a mile above St. Ubes, called the ' Pedra Furada ' or perforated rock, which belongs to this formation, and consists of irregular, perpendicular tubes varying from half an inch to a foot in diameter, of a very ferruginous sandstone, united by horizontal layers of the same substance : the cement of the sandstone is phosphate of iron ; the centres of the tubes and the spaces between them are filled with ochreous sand, which passes into the usual sand of the neighbourhood. The rock is about twenty feet in height and width ; its extent inwards from the river is concealed by the overlying sand.

I did not explore the whole of the boundary of the upper tertiary sand, which includes considerably more than 1000 square miles. North of the Tagus it is found

only in low lands skirting the river near Santarem and Cartaxo; but it covers as much of the country between the Tagus, the Sado, and the sea, as would be cut off by a line drawn from Abrantes to Alcacer do Sal, with the exception of two ridges of hills of older formations, which will be best seen by reference to the annexed map. It usually rests upon the Almada beds; but between the lagoon of Albufeira and Cape Espichel it overlaps that formation, and rests upon the red sandstone. Its greatest elevation above the sea is about 150 feet.

I observed no organic remains in this formation.

The sands of the upper division present barren, dreary heaths, which hardly admit of any cultivation; but the fir thrives in the ferruginous sands of the lower division, which are cultivated here and there, though to little advantage. The only interest attached to this most barren formation arises from its mineral contents, which are richer than might be expected from so modern a deposit.

Mineral Contents.—A mine of quicksilver was discovered in the beginning of the last century at Coina, by Manoel da Cruz Santiago, an individual celebrated in the annals of Portuguese mining. He had observed that a spring of water in the centre of the village was strongly impregnated with mercury. No account of this mine has been published, and I could only learn that it was worked profitably at a very slight depth until 1801, when it was abandoned, all the quicksilver having been extracted, which their method of working enabled the miners to reach. From the position of the spot, I have no doubt that it was worked in the lower beds of this formation.

From a very early period the sands of the Tagus have been stated to contain gold-dust. It appears to be disseminated in very small quantities through the whole of the lower division of this formation, as it has been found in several places where the heavier particles of the sands of that division are separated by the action of rain or of the streams of water. The only spots where workings for gold-dust have been carried on regularly to any extent, are on the coast near Adiça, about ten miles south of the mouth of the Tagus. The beach lies upon a bed of blue marl belonging to the Almada formation, but the cliffs consist of the ferruginous sands. The numerous springs which flow through them wash down large quantities of sand, and the waves give them another washing upon the beach; the workmen dig up this sand and submit it to a further process of washing, and the residue is treated with mercury to separate the gold.

Baron d'Eschwege, who superintended these works for some years, has given an account of them in the eleventh volume of the Memoirs of the Academy of Sciences of Lisbon, and he has appended to it a statement of the result of the operations. He mentions that works were carried on at Adiça in the fifteenth century as long as they were profitable, and that they were recommenced in 1814 and continued till 1826, when they were again found a losing concern. During these thirteen years 373 marks of gold were collected, varying in fineness from twenty-two to twenty-three carats. It appears that a remunerating quantity of gold is collected only after the natural washings by the springs and the sea have gone on for a considerable number of years; and therefore, another long interval must elapse before the washings can be again profitable.

2. *Almada Beds.* (Pl. XIV. and Pl. XV., Sect. 1, 3, 6 to 9, and 11 to 13.)

This is the most interesting formation of the tertiary series, in consequence of the variety of its rocks and the abundance of its organic remains. It may be

studied very conveniently in the cliffs opposite to Lisbon, where the following observations were principally made. Unfortunately, the lowest beds are not there exposed, and they vary so much in thickness and appearance, within very short distances, that a stratigraphical table of the formation cannot be completed from observations made elsewhere.

The following is a tolerably correct list of the beds in the cliff, near Almada:

	Feet.
Yellow calcareous sand, containing a few shells	50
Limestone, full of shells	2
Marly sand of a bluish colour, containing oysters, pectens, &c.	10
Limestone, full of casts of shells	2
Blue marl, with many shells	6
Sandy limestone, ditto	1
Yellow sand, containing Echini, and a few shells	10
Greenish sand, with few shells; in this bed small quantities of quicksilver have been found	10
Brown clay	3
Blue clay, with thin layers of shells (*b*)	30
Sands and limestones, which I had no opportunity to observe accurately, as they occur where the cliff is inaccessible	50
Sandy limestone	3
Carried forward	177

	Feet.
Brought over	177
Limestone, full of shells	1
Sand	2
Limestone, full of shells	3
Sand	10
Rubbly limestone, with oysters and other shells	5
Sand, containing calcareous concretions	4
Rubbly limestone, few shells	4
Hard limestone, many shells	10
Sandy limestone, a bed of oysters	5
Yellow sand, some oysters	12
Sandy limestone	3
Yellow sand, few shells	12
Sandy marl, ditto	6
Sandy limestone, pectens, &c.	12
Yellowish sand, with a few fragments of shells	40
Yellow marly sand, with few shells	12
Sand, containing some mica	13
In all about	331

This table is incomplete at both ends; very little is wanting above it—I cannot say how much is wanting below.

At Adiça the uppermost beds consist of

Yellow calcareous sand	10 feet.
Blue sandy marl, with many shells	20 —

the latter resting upon a calcareous bed. If these strata were placed at the top of the preceding list, the upper part of the formation would probably be completed; the blue marl of Adiça would then correspond with that of the valley of Piedade to the S.E. of Casilhas, where the uppermost beds cannot be distinctly seen.

The most marked stratum of the series, is the blue clay (*b*) mentioned near the middle of the table; but this bed is in some places so thin as not to be easily recognized. Were it thought convenient to separate the formation into parts, the most natural arrangement would be

Upper Limestones and Sands,
Blue and brown Clay,
Lower Limestones and Sands;

but as some species of shells occur both above and below the clay, the subdivision would not be of much value.

Quicksilver has been found in several places in the sand immediately above the blue clay, but in very insignificant quantities.

Not having examined this formation in equal detail elsewhere, I can give but a general sketch of its position. On the southern side of the Tagus, it forms the cliffs from Trafaria to Casilhas, the dip of the strata being from 10° to 15° S.E. There are three considerable faults in these cliffs. At Casilhas the beds to the west of the village are raised about 100 feet above their prolongation on the other side of the street; at Fonte de Pipa, on the contrary, those on the west of the fault are about 130 feet below the same beds to the eastward; and at San Lourenço a similar dislocation has taken place to the extent of about eighty feet. Owing to these faults, a more extensive section of the formation is obtained than the cliffs, which are only 280 feet high, would otherwise afford.

North of the Tagus the Almada beds begin on the coast, a little to the west of Fort St. Julian, resting on the secondary limestone, and they reach as far as the Oeiras River, where they are cut off by a fault,—one bank of the river consisting of these beds, and the other of the secondary limestone; both rocks being also horizontal and at the same level.

For about ten miles to the eastward, the upper beds appear to have been denuded; and the tertiary strata are seen only at the tops of some hills about Santa Catarina and San Jozé de Riba-mar. These outliers consist of the lower tertiary conglomerate, occasionally covered by small patches of the Almada beds. (See Plate XV. Sections 1 and 3.)

The Almada beds reappear in the middle of Lisbon, and continue along the north bank of the Tagus to the little village of Verdelha. At their western edge, under Lisbon, the upper beds rest unconformably upon the secondary limestone (Plate XV. Section 3), the Rua de San Bento marking very nearly the line of union of the two formations. To the north-west, the Almada series is bounded by the valleys of Odivellas and Vialonga, and rests conformably upon the lower tertiary conglomerate. Throughout this district, the dip of the Almada beds is from 5° to 10° S.E. The lower streets of Lisbon stand upon the blue clay, which may be traced for some miles up the Tagus between high- and low-water levels, all the cliffs toward the river consisting of the deposits above that stratum. The lower beds may be seen cropping out on the land-side of the deposit, but there is no good section of them there.

The Almada beds in this part agree so nearly in dip and strike with those on the south bank of the Tagus, and with the detached outliers between Lisbon and the sea, as to prove that they were once continuous, and have been separated by denudation.

Beyond Verdelha the formation is not visible within the district described in

this memoir, the north bank of the Tagus being formed of older rocks; but it occurs again near Cartaxo, Santarem, Thomar and Abrantes, the last town being its extreme limit to the eastward. I do not know if it exists along the eastern edge of the basin, but to the south it forms the hill of Alcacer do Sal, where it rests upon slate-clay, the intermediate secondary formations being absent.

In the centre of this tertiary district, a ridge of older rocks extends from Palmella to Cape Espichel, skirted by a zone of the Almada beds from St. Ubes to Palmella (Sect. 9, 11 and 13), and thence westward through Azeitão nearly to the coast, where they are concealed by the upper tertiary sand, overlying both these and the older rocks. Throughout this circuit the Almada beds rest upon red sandstone, and are more elevated than in the localities before described, the dip being usually from the subjacent formation: thus between St. Ubes and Palmella their inclination is about 30° S.E., and from Palmella to Azeitão between 25° and 30° N.E., being rather greater in the lower than in the upper beds; but at Palmella, where the two lines of elevation meet, the disturbance has been more considerable, and the dip at the Castle-hill varies from 15° to 50° N. It is probably from the same cause that the formation attains its greatest height at this point, the castle being 930 feet above the sea (Pl. XV. Section 9).

A detached mass of the formation also occurs at the western end of the Serra de San Luiz, between St. Ubes and Azeitão, abutting unconformably against the edges of the elevated beds of red sandstone, which form that steep hill; its dip, about 30° N., agrees with that of the same beds in the neighbouring Serra de Azeitão (Plate XV. Section 1), so that the valley between must have been occupied originally by the tertiary beds.

The most violent dislocation of this formation is on the bank of the Sado, at the foot of the Serra de Vizo (Plate XV. Section 13), where an outlying mass of the limestone dips at 80° toward the older red conglomerate, having been elevated beyond the perpendicular.

I did not observe the blue clay in this neighbourhood, nor could I examine the beds enough to ascertain to which part of the formation they belong; they are mostly coarse, rotten, sandy limestones, containing many casts of shells, and probably belong to the lower division of the formation.

This deposit affords the best land in the neighbourhood, both for corn and vines; and it is peculiarly suited to the growth of the olive, which thrives to greatest advantage in a light and semi-calcareous soil.

Mr. George Sowerby has examined my fossils, and also an excellent collection made near Lisbon by James Smith, Esq., of Jordan Hill, who has very kindly allowed me the fullest use of the information derived from it; among them Mr. Sowerby has found the following shells, besides about twenty undescribed species.

Other localities where they have been found are marked against them. It will be observed that there are more of the shells of Bordeaux than of any other locality, but not sufficient to identify the two deposits.

Vermilia triquetra, *Lam.* Recent and Crag.
Lucina columbella, *Bast.* Bordeaux.
Lutraria sanna, *Bast.* Bordeaux.
Cyprina æqualis ? *Min. Con.* Crag.
Cytheræa incrassata, *Desh.* Paris Basin.
Venus Brocchii, *Bronn.* Subapennines.
Cardium hians, *Brocchi.* Subapennines.
——— paucicostatum, *Sow. Conch. Illust.* Recent.
——— multicostatum, *Bast.* Bordeaux.
Panopæa Faujasii. Crag.
Solen antiquatus ? Recent.
Pectunculus pulvinatus. Paris Basin.
Pinna affinis, *Min. Con.* London Clay.
Spondylus quinquecostatus, *Desh.* The Morea.
Anomia ephippium, *Goldf.* Subapennines.
Ostræa flabellulum, *Min. Con.* London Clay.
——— Boblayi, *Desh.* The Morea.
——— longirostris, *Goldf.* Saxony and Andalusia.
——— hyotis, *Linn.* Recent.
Pecten maximus, var. ? *Lam.* Recent.
——— squamulosus, *Desh.* The Morea.
——— Pandora, *Desh.* The Morea.
Natica glaucina, *Lam.* The Morea.
Natica clausa, *Sowb.* Recent.
Ampullaria perusta ? *Desh.* Vicenza.
Sigaretus canaliculatus, *Bast.* London Clay and Bordeaux.
Turritella proto—, *Bast.* Bordeaux.
——— cathedralis, *Bast.* Bordeaux.
——— terebralis, *Bast.* Bordeaux.
——— turris, *D'Orb.* Bordeaux.
——— imbricataria ? Paris Basin.
Solarium neglectum, *Bellardi.* Piedmont.
Phorus agglutinans. London Clay.
Pleurotoma ramosa, *Brocchi.* Subapennines.
Pyrula ventricosa ? Recent.
——— condita, *Brongn.* Vicenza.
——— rusticula, *Bast.* Bordeaux.
Fasciolaria Burdigalensis, *Bast.* Bordeaux.
Murex trunculus, *Linn.* Recent.
Ranella marginata, *Brocchi.* Recent and Subapennines.
Eburna spirata ? *Lam.* Recent.
Buccinum veneris, *Bast.* Bordeaux.
Cassis Thesei, *Brongn.* Vicenza.

Some papers laid before the Society by Colonel Silvertop (Proceedings, vol. i. pp. 216, 234 and 485, and vol. ii. p. 80), afford the means of comparing the tertiary basin of the Tagus with those of the South of Spain. The marine deposits of Alhama, Lorca, Baza, etc., coincide with the Almada beds; as they contain in great abundance the *Ostræa longirostris*, which is one of the commonest shells at Almada, and a *Pecten* resembling the *P. pleuronectes*, but which Mr. George Sowerby considers a distinct species, and which is not uncommon in the cliffs at Almada. From some observations I made in crossing those parts of Murcia, I had considered the deposits of Alhama, etc., equivalent to the Almada beds, and Col. Silvertop's memoirs confirm that opinion.

3. *Lower Tertiary Conglomerate.* (Pl. XIV. and Pl. XV. Sect. 1, 3, 6 to 8.)

The oldest tertiary beds near Lisbon consist of a variety of distinctly stratified conglomerates, underlying the calcareous beds of the Almada formation. They are of limited extent, but vary very much in character; yet as they attain a considerable thickness, and agree in having all been formed during a period when a violent and extensive denudation of the older rocks was going on, they seem to deserve to be considered as a distinct formation.

The principal deposit of these rocks may be traced bounding the Almada beds from Alverca and Verdelha through Vialonga and Tojal to Loures, where it ex-

pands to a breadth of four miles; and thence it may be followed along the narrow valley which passes between Odivellas and Lumiar to Bemfica, where, turning towards Lisbon, it thins out and gradually disappears near the gate of San Sebastião de Pedreira.

At its northern extremity this deposit rests upon the red sandstone, but throughout the remainder of its course upon basalt: the beds dip conformably under the Almada formation at angles of 10° or 15° S.E., but the inclination increases in the lowest beds to 30°.

This formation is well displayed where it is crossed by the road to Canessas, the beds there exposed, in a descending order, being as follows:—

The lowest strata of the Almada formation.
Marl.
Soft limestone, containing pebbles of limestone and flint.
Limestone, inclosing angular fragments and rounded pebbles of limestone, the whole forming a hard rock.
Calcareous beds, containing pebbles of limestone.
——————————— flint.
Sandstone, passing into coarse gritstone and rough conglomerate, with large siliceous pebbles.
Sand and gravel.
Clay and marl.
Clay formed of the detritus of basalt.
Decomposed basalt.
Compact basalt.

The thickness of the formation is here about 200 feet.

Near Loures and Tojal there is less of the harder conglomerates, and a greater proportion of marl, gravel, and the soft calcareous conglomerates.

Many of the basaltic hills along the bank of the Tagus below Lisbon, are capped with a bed of clay containing basalt in different states of decomposition, upon which the Almada beds rest near Santa Catarina and San Jozé de Riba-mar. This clay and decomposed basalt are sometimes fifty feet thick, and are without doubt of the same age as the similar beds near Loures and Odivellas, and must be referred to this formation. (Pl. XV. Sect. 1, 3, 6 and 7.)

I did not meet with the conglomerate south of the Tagus. I did not find any organic remains imbedded in it.

The separation between the tertiary and the secondary series can nowhere be more distinctly marked than in the neighbourhood of Lisbon. The secondary rocks were both disturbed and denuded previously to the deposition of the tertiary, which lie not only upon the newest secondary formation, but also upon rocks of very different ages. The separation between them is still further marked by an immense mass of basalt which overflowed the secondary formations before the

deposition of any of the tertiary strata, and contributed by its degradation to form the earlier tertiary deposit.

The description of the basalt will be given in that part of the paper which relates to the igneous rocks.

Secondary Formations.

This class of deposits consists of, 1. Hippurite limestone. 2. Red sandstone. 3. Espichel limestone. 4. Slate-clay and shale. 5. San Pedro limestone; and 6. Older Red conglomerate.

1. *Hippurite Limestone.* (Pl. XIV. and Pl. XV. Sect. 1, 3, 6 to 8.)

The uppermost secondary formation consists of calcareous beds varying from soft and argillaceous limestone to beautiful hard marble. I have called it the Hippurite limestone, as some of the beds abound with fossils belonging to the family of *Rudistes*, and nearly related to the genus *Hippurites*. It usually rests conformably upon the red sandstone.

Hills composed of this limestone form a very important feature in the country north and west of Lisbon, but I did not observe the formation south of the Tagus.

A very good section is exposed on both sides of the narrow valley of Alcantara, close to Lisbon, where the following beds occur:—

Soft argillaceous limestone, alternating with thin beds of marl	40 feet.
Grey marl	6 —
Rubbly argillaceous limestone, containing *Sphærulites*	50 —
Limestone, containing *Sphærulites* and other shells belonging to the family of *Rudistes*	30 —
Soft argillaceous limestone	20 —
Hard, compact, white limestone, with numerous interstratified beds of flint	50 —
Beautiful, hard, compact, white limestone	100 —

This list does not include the whole thickness of the formation. The cliffs between Fort St. Julian and Cascaes consist of alternations of marl and grey limestone, the marl predominating in the upper, and the limestone in the lower part; and they are probably the highest beds of the formation. A good section of the lowest beds is in a ravine through which the road from Tojal to Bucellas passes. The limestone is there of a coarse texture and dark grey colour, with rather a slaty fracture, and forms beds three or four feet thick, with thin partings of marl. Putting these sections together, the formation will be found to exceed 500 feet.

This limestone composes several distinct tracts; the most northerly being a line of bold hills extending from Cercal to Villa Franca, rather beyond the district which I examined. Another narrow zone of Hippurite limestone ranges from Bucellas westward to Pero Pinheiro; resting to the north upon red sandstone, and having its southern edge concealed by basalt. Only the lower beds are visible at Bucellas and

Montachique; and these thin out gradually to the westward, being replaced by the upper beds at Pero Pinheiro, where the formation is of inconsiderable thickness, and consists only of the latter. The large quarries at that village, which furnish pretty, light-coloured marbles, are worked principally in the beds which contain the *Sphærulites*. Along this line there is a slight dip to the S.E.

Another distinct range of Hippurite limestone begins on the south of Loures, and reaches to the Bay of Cascaes. On the northern side it rests upon the red sandstone, and upon the south and east is overlaid by basalt. From Loures to the west of Bellas the beds dip S.E. at an angle varying from 30° to 50°, but between Cacem and the coast, the inclination is usually less considerable, and in the sea-cliffs the beds are nearly horizontal. Between Loures and Bellas, the middle and lower parts of the formation are exposed; about Cacem the middle, and near the coast the upper beds. The usual conformity between the Hippurite limestone and the red sandstone does not hold good throughout this range, for, towards Cascaes, nearly horizontal beds of the limestone rest upon inclined strata of the sandstone; still the direction of the dip of the two formations is the same. (Pl. XV. Sect. 7.) The limestone range widens out very much at its southern extremity; the basalt capping its higher hills.

The narrow valley of Alcantara, on the west side of Lisbon, is the line of a considerable fault which has raised to view the Hippurite limestone: the beds on the two sides of the valley correspond in altitude, but dip from the valley in opposite directions, on the west side at 15°, on the east at 10°. An anticlinal line of more violent disturbance crosses the former from Campolide to Mon Santo, and it is to this cause that Mon Santo owes its elevation. Where the two faults cross, the rocks are very much fissured and disturbed, and great landslips have taken place. In one quarry I noticed six or eight faults, where the sides of the fissures had been rubbed to a beautiful polish. This spot is called Terremotos, and the disturbance of the rocks is frequently attributed to the great earthquake, but all the contemporary accounts of that catastrophe state, that this neighbourhood suffered very slightly.

Organic Remains.—Among the fossils of this formation are the following:—

Exogyra plicata, Goldfuss, 82, f. 5, a shell found in the chalk in France and Belgium; it occurs also in the Espichel limestone (See p. 121.)

——— *conica*? Min. Conch., a very imperfect specimen.

Pecten quadricostatus, Min. Conch., 56, f. 1 and 2, common in the upper and lower green sand in England, &c.

——— *striato-costatus*, Goldfuss, 93, f. 2, found in the upper chalk in Germany.

Nerinea Borsonii, Bronn, an internal cast.

——— *nodosa*? Voltz, an internal cast, apparently of this species, which has been found in the coral rag.

Sphærulites ventricosa, Des Moulins.
——— *cylindracea*? Des Moulins.
——— *cristata* ,,

The last three species are found in the chalk in the South of France.

Also a very remarkable shell belonging to the family of *Rudistes*, which is, I believe, undescribed; agreeing in form with *Diceras*, having one valve spiral and the other curved; but perforated longitudinally by parallel pores, reaching the whole length of the shell, and open towards the junction of the valves.

2. *Red Sandstone Formation.* (Pl. XIV. and Pl. XV. Sect. 1 to 4 and 6 to 13.)

Below the Hippurite limestone is a very extensive series of deposits consisting principally of ferruginous sandstone, but containing also beds of sand, marl, and limestone. The following is the usual order of the strata:

Sandstones, alternating with sand, the whole very ferruginous.
Marls of various colours, alternating with sand.
Sandstones, alternating with sand.
Calcareous sandstones and coarse limestones, alternating with sand and sandstones, and occasionally with marl.
Coarse sands, sandstones, and coarse gritstones.

The whole series divides naturally into three parts:

1. Ferruginous sandstones and coloured marls.
2. The calcareous division.
3. Gritstones, &c.

The different divisions pass so gradually into one another, that I have not attempted to separate them into formations.

The extent of country occupied by this series of strata is very considerable, but it would be tedious to describe its boundaries in detail, and they may be better seen on the map. The principal deposit reaches from Alhandra, on the Tagus, to the coast north of Colares, and occupies nearly the whole country northward of that line to Leiria, far beyond the range of country described in this paper; but in that district, it is partly concealed by the overlying Hippurite limestone, forming the hills which range north-west from Villa Franca. In the portion more immediately under consideration, the sandstones of the upper division occur along the southern edge of the deposit from Bucellas to the Atlantic; the central calcareous beds may be traced from Alhandra to Ericeira, passing the two villages of Enxarra and Mafra; and the grits and coarse sandstones of the lower division lie further north, about Sobral, San Sebastião, and Torres Vedras. The usual strike of the beds is from E.N.E. to W.S.W., and the prevailing dip is to the S.E.; but the whole country is so cut up by innumerable faults, that beds may be found dipping in every direction and at every angle: this is particularly the case about Mafra.

A very considerable fault, extending westward from Alhandra, has modified the

surface of that part of the country. On the south side of the fault, the calcareous beds of the middle division rise into the bold abrupt hills which form the eastern end of the lines of Torres Vedras, while on the north side the uppermost sandstones occur, overlaid by the Hippurite limestone; and they form the surfaces of the country to the northward. Judging from appearances, this fault extends a long way into the interior; but I followed it only four miles, from Alhandra to Trancozo.

One of the upper beds of the calcareous division resembles so closely the usual character of the Hippurite limestone, that I could not determine whether the limestone hill at Alhandra belongs to this formation, or is an outlying mass of that limestone.

The tract of red sandstone, next in importance, forms a narrow band, reaching from the neighbourhood of Loures to Cape Sinchette. From its northern extremity to the Cascaes river the beds dip to the S.E., at angles varying from 20° to 60°, and at Sabugo they are perpendicular. They consist principally of the sandstones of the upper division, but the coloured marls are seen near Cacem, on the Cintra road, and the calcareous beds occur where the deposit widens out towards Sabugo; the Mafra road crosses them in that neighbourhood for about three miles; they occur also between Manique and Cascaes.

The Cascaes river follows the line of a considerable fault, and on its western side the calcareous beds are exposed with a prevailing dip of 5° or 10° to the south: in this neighbourhood also the strata are disturbed by many small faults.

The red sandstone ranges, on the south of the Tagus, from near Palmella and St. Ubes to the coast north of Cape Espichel. The strike of the beds is nearly from E.N.E. to W.S.W., and their usual dip N. or N.W., at a high angle: this part of the formation has been dislocated by many considerable faults, but as they affect also several of the older rocks, all the disturbances of this neighbourhood are described together. (See p. 129, *et seq.*)

The upper division of the formation is better exposed near Palmella and St. Ubes than in any other part which I examined, except the hills behind Bellas north-west of Lisbon; it consists here of

1. Very ferruginous loose sand and gravel.
2. Fine sandstone, sands and marls of various colours.
3. Ferruginous sandstones.

The gravel is more abundant than usual, occupying some picturesque valleys between Azeitão and St. Ubes; while the adjacent barren Serra de San Luiz, consisting of the succeeding beds of the same formation, rises abruptly to more than 1200 feet above the sea.

The calcareous beds may be traced from the coast on the north side of Cape

Espichel to Cezimbra, and again in the cliffs of the Serra de Risco; the lower sandstone division is visible only on the cliff, near the Chapel, at Cape Espichel: with these exceptions, this district consists entirely of the beds of the upper division.

The country occupied by the upper strata of this formation is generally intersected by irregular valleys and ravines. The lower lands are fertile and wooded, but the hills are open and covered with heath: the calcareous rocks of the middle division form wild dreary hills, hardly capable of cultivation: and the lower sandstone division varies much, affording barren hilly districts and others of greater fertility. All the sandstones occasionally form extensive plains covered with pine-woods.

The connexion of the red sandstone with the older rocks is exposed in few places near Lisbon. On the north of Cintra the sandstone overlies all the older formations, resting almost horizontally upon the inclined strata of Espichel limestone (Sect. 2 and 4), slate-clay, and San Pedro limestone, and upon the granite; and on the south of the Cintra hills, upon the Espichel limestone (Sect. 1 and 7). South of the Tagus it lies, with every degree of want of conformity, upon the limestone of the Serra de Arrabida, and upon the elevated peaks of the older red conglomerate of the Covoens and the Serra de San Luiz (Sect. 11 to 13).

Mineral Contents.

Lignite has been found in this formation in many places, occasionally in sufficient quantity to lead to unsuccessful search for coal: the principal localities are Ericeira, and the neighbourhoods of Torres Vedras, Cascaes and Cape Espichel. I examined only the two last.

The cliff, a little to the east of Cascaes, gives the following very good section of the lower beds of the upper sandstone division:—

1. Fine-grained white sandstone.	
2. Coarse sandstone, slightly sulphureous	5 feet.
3. Coarse quartzose gritstone, very sulphureous	$\frac{1}{2}$ —
4. Thin layers of marl, separated by seams of vegetable matter, and containing abundance of sulphur and some iron pyrites	$1\frac{1}{2}$ —
5. Fine sandstone, with thin layers of lignite, containing impressions and pyritous casts of vegetables	1 —
6. Bituminous marl, with sulphur	$1\frac{1}{2}$ —
7. Fine sandstone, very sulphureous	3 —
8. Coarse sandstone, slightly sulphureous	5 —
9. Hard compact sandstone, containing very little sulphur.	

The lignite varies from a quarter of an inch to eight inches in thickness. The sulphur effloresces from some of the beds in great quantities. The vegetable impressions are fragments of leaves and stalks too imperfect for determination; the only interesting specimens met with being small seed-vessels. The beds have been thrown into great confusion at this spot by a basaltic dyke (Pl. XV. Sect. 3 and 10).

The lignite beds, near Cape Espichel, occur in the calcareous division of the formation; and the following section may be seen in the cliff, about a mile to the north of the Chapel:—

Limestone, alternating with sandstone.	
Limestone	3 feet.

Limestone, very sandy	3 feet.
Marl	2 —
Sulphureous marl	2 —
Lignite, very sulphureous	1 —
Sulphureous marl	4 —
Marl of various colours	20 —
Limestone, alternating with sandstone.	
The coarse sandstones of the lower division of the formation.	

We were told that the lignite may be traced along the cliff northward for several miles to Aganheira, and that there it is thicker and of better quality.

To the eastward of Cezimbra a similar section of sulphureous marls, accompanied by lignite, sand, sandstones and limestones, is exposed on the beach: the beds of lignite are not more than half an inch in thickness, and were it not for the abundance of sulphur, might easily be overlooked.

The resemblance of the sulphureous deposits at Cascaes and Cape Espichel is so great, that they must be considered as identical, although at Cascaes they occur above the calcareous beds, and at Cape Espichel among them: this lessens the importance of the divisions of the formation.

The tepid springs of Estoril, near Cascaes, rise so close to the sulphureous beds, that the water probably derives its virtues from them: the celebrated hot springs of Caldas da Rainha in Estremadura rise through the upper division of this formation, and may possibly owe their sulphureous qualities to similar beds.

Gypsum has been worked in some quantity near the village of Sta Anna, three miles from Cezimbra. I did not examine the spot, but have reason to believe that it is in immediate connexion with the sulphureous marls.

Organic Remains.—The following fossils have been found in the calcareous division of the formation:

Terebratula biplicata (var. *b.*), Sow. Min. Con., 90, f. 2 and 3, a shell of our green sand.

Perna rugosa, Goldfuss, t. 108, f. 2, found also "in stratis arenaceo-oolithicis Westphaliæ."

Trigonia (*Lyrodon*, Goldfuss, t. 136, f. 5, *e*,) figured by him as a variety of *T. literata*, from which it is apparently distinct.

Astræa, two species, one of which bears a strong resemblance to a coral common in the coral rag of Steeple Ashton.

3. *Espichel Limestone.* (Pl. XIV. and Pl. XV. Sect. 1, 2, 4, 5, 7, 9, 12, and 13.)

Near the Cintra hills the red sandstone rests upon a calcareous formation of very considerable thickness, to which, from its also forming the point of Cape Espichel, I give the name of Espichel limestone. Its principal deposit is a flat barren tract, which encircles the whole range of the Cintra hills, and attains its greatest breadth where the road from Lisbon to Cintra crosses the Charneca, but in other parts it is of little extent. It rests throughout conformably upon the slate-clay, dipping from the Cintra hills as from a centre at angles varying from 20° to 75°. There is an exception to this dip on the north of Cintra, where a line of disturbance, ranging east and west from Algerão to the coast, has raised some of the beds into a saddle, and formed two parallel faults. This dislocation may be seen to the north and north-east of the town of Cintra, and in the cliffs near the Praia de Maçaãs (Sect. 2, 4 and 5), but it is concealed near Colares by the red sandstone which overlies part of the formation.

In the whole of the district round Cintra, the formation consists of thick beds of coarse grey limestone, alternating with thinner beds of shale or marl: at the bottom of the formation the limestone beds are thinner, of a darker colour, a more earthy structure, and a slaty fracture.

The hills along the coast, from Cezimbra to Cape Espichel, consist of the same formation. Beds of coarse grey limestone alternate with layers of shale, marl, and sandy clay, but the argillaceous beds are less important there than near Cintra. The dip of the strata is nearly north, varying from 45° to 70°; but at Cezimbra Castle, an igneous rock has caused great disturbance in them. The lowest beds are not exposed in this district, nor is the formation upon which they rest.

The lofty ridge of the Serra de Arrabida may possibly belong to the same formation, but I have no conclusive evidence upon that point. It consists of a compact, light grey limestone, with partings of marl only between its lower beds, which have a similar earthy character and slaty fracture with those near Cintra. It agrees very nearly in strike and dip with the limestone ridge of Cape Espichel, from which it is separated by a fault at Cezimbra; but the absence of the alternating shales and marls, so marked near Cintra and Cape Espichel, renders the identity of the two deposits doubtful, and, unfortunately, I met with no fossils in the limestone of the Serra de Arrabida.

The strike of the beds in the Serra de Arrabida is nearly east and west, and their prevailing dip is north at a high angle; but at the western end of the Serra the dip varies to N.W. and N.E., and on the northern side of the Serra de Vizo, it is 45° S. At these last-mentioned spots, the limestone rests unconformably upon the older red conglomerate.

Near St. Ubes are two detached points of limestone which appear to belong to the rock of the Serra de Arrabida: the one forms a conical peak on the east side of the road from Palmella to St. Ubes, its beds dip S.E. about 80° (Sect. 9.); the other rests upon the older red conglomerate at the southern side of the Serra de San Luiz, and dips 45° S. (Sect. 13.); both these masses approach to conformity with the limestone of the north side of the Serra de Vizo.

Organic Remains.—The following shells were found in this formation:—

Trigonia scabra, Deshayes, *Coquilles Caractéristiques des Formations*, t. 13, f. 4 and 5, a species considered characteristic of the green sand in France, and common in the green sand at Blackdown, Devonshire.

Nerinea Defrancii, Deshayes, *Expédition de Morée*, t. 26, f. 1 and 2 (*N. suprajurensis* of Voltz), found also in the coral-rag at St. Mihiel, in the Neocomian beds at Neuchatel, and in the upper green sand of the Morea.

Nerinea ——, another species undescribed.

Ostræa colubrina, Goldfuss, t. 74, f. 5, found in the coral-rag of Wurtemberg.

Exogyra plicata, Goldfuss, t. 87, f. 5, a species found in the chalk in France and Belgium, and abundant in the Hippurite limestone near Lisbon (*ante* p. 116).

4. *Slate-clay and Shale with trap.* (Pl. XIV. and Pl. XV. Sect. 1, 2, 4, 5 and 7.)

In the neighbourhood of Cintra, the Espichel limestone rests conformably upon an argillaceous formation, which constitutes a low rounded ridge, encircling the Cintra hills, which may be most advantageously examined at Ramalhão and Linhó.

The upper beds consist of shale and schist varying much in character; below them are numerous beds of slate-clay alternating with a variety of igneous rocks, and the lowest part is a thick deposit of dark shale. In no portion did I find any organic remains.

The beds of igneous rocks vary from five to twenty feet in thickness, and the shale-beds are still thicker. The whole are regularly interstratified without any signs of disturbance. The shale rests with perfect conformity upon the San Pedro limestone, and dips on all sides from the axis of the Cintra chain at angles varying from 30° to 60°.

Near Ramalhão, where the series is most developed, there are twenty or thirty distinct alternations of igneous rocks. On the north side of Cintra the formation is less important, and becomes gradually thinner; and in the cliffs at the Praia de Adraga it does not exceed 200 feet in thickness, and contains only one igneous bed, about twenty feet thick. I did not follow the formation quite round the south of Cape Rock, and do not therefore know its exact importance at that point.

It is difficult to account for these alternations of igneous and aqueous beds, except by supposing that the igneous matter was poured out at intervals during the accumulation of the shale. There is no evidence to prove, whether these eruptions took place from the spot, where the granite hills of Cintra were afterwards elevated. The original formation was probably shale, which was altered into slate-clay by the heat of the igneous matter.

The trappean rocks vary much in character within a few yards in the same beds; some portions being basaltic, others sienitic.

5. *San Pedro Limestone.* (Pl. XIV. and Pl. XV. Sect. 1, 2, 4, 5 and 7.)

Below the last formation occurs a considerable deposit of limestone, which rests upon the granite, and forms an inner zone around the Cintra hills.

The limestone in the upper beds is dark grey or black, and of an earthy structure, and in some places it is very bituminous, and passes into swinestone; but as it approaches the granite, it gradually changes into a crystalline marble, and from that into calcareous spar. The formation is well exposed on the road-side, and in

some large quarries at the village of San Pedro, from which I have taken its name. At this spot the beds succeed each other in the following order:—

Dark grey, compact limestone, several hundred feet thick.	
Grey limestone, with slight traces of crystalline structure, in the lower part becoming granular.....	200 feet.
Coarsely crystalline marble, white, or white and grey	100 —
Irregularly crystallized calcareous spar, usually grey	100 —
Calcareous spar, breaking into large crystals; colour bluish-white.	
Granite.	

The same gradual change may be traced around the Cintra hills, wherever the limestone can be seen resting upon or approaching the granite. In some spots the crystalline marble is quite equal in colour to the Carrara, but it is too soft for use.

The stratification of the limestone is hardly altered by the change of structure, but the crystalline beds are thicker than the others. The alteration is very gradual, the characters of each bed being uniform, and a slight change taking place between it and the one next below.

The strata dip from the granite at angles varying from 40° to 70°; near San Pedro they are considerably dislocated.

Organic Remains.—I found in the limestone the casts of one univalve and one bivalve, but too much crushed to admit of determination.

6. *Older Red Conglomerate.* (Pl. XIV. and Pl. XV. Sect. 9, 11 and 13.)

On the west of St. Ubes a coarse conglomerate rises into hills of considerable height, in a position entirely unconformable to the neighbouring formations. There is no clue to its place in the series, except that it is more ancient than all the surrounding strata; but as it does not occur near Cintra, there is no evidence of its being older than all the formations just described in that district, for the altered characters of the two lowest of those deposits make it impossible to compare them safely with rocks elsewhere. In this uncertainty, I have left the account of the formation to the end of the aqueous deposits; expecting that it will hereafter be found to be older than any of the strata yet noticed.

The conglomerate usually consists of rounded pebbles from half an inch to more than a foot in diameter, firmly cemented in coarse ferruginous sandstone, and composed mostly of white or ferruginous quartz; but pebbles of jasper and mica-slate, and a few of limestone also occur. The harder beds have been used for ornamental work in most of the old churches about St. Ubes; but the stone will not take a good polish, owing to its unequal composition.

The conglomerate forms the highest ridge of the Serra de Covoens, at the eastern

extremity of which it is laid open by the St. Ubes' road. The strike is there nearly E. and W., and the dip N. at angles varying from 30° to 50°. The eastern end of the Serra de San Luiz consists of the same rock, also dipping N. at about 50°. The conglomerate forms all the higher parts of the Serra de Vizo, and the coast to the beginning of the Serra de Arrabida. Along this line there is great variation in the dip of the beds: at the east end of the Serra de Vizo, the inclination is south about 50°; more to the west it is in some places vertical, and at others 50° to the north; while at the Torre de Outão, at the foot of the Serra de Arrabida, it is N.E. about 70°.

The lowest beds of the formation are not seen in this neighbourhood, nor is the rock upon which they rest.

A conglomerate of similar character is largely developed upon the banks of the Vouga, and overlies mica-slate a little to the south of Oporto.

PART II.—Igneous Rocks.

It remains for me to describe the igneous rocks which occur near Lisbon, and to point out the alterations which they appear to have caused in the position of the aqueous formations.

Basalt. (Pl. XIV. and Pl. XV. Sect. 1 to 3, 6 to 8, 10 and 12.)

The principal deposit of this rock forms one of the most important features in the geology of the district; but it extends so irregularly on the west and north of Lisbon, that its range can be understood only by referring to the map. Its extreme length, from Sta Catarina on the Tagus to its northern boundary near Bucellas, is about twenty miles, but its width varies greatly. Besides this immense sheet of basalt, many of the hills around Oeiras, near the mouth of the Tagus, are capped by masses of the same rock, which have evidently been separated from it by the excavation of the intervening valleys. The extent of country occupied by this deposit cannot be less than eighty square miles, the whole of which appears to have been covered by one eruption; and if, as is probable, the basalt reaches far under the tertiary beds, the amount of the eruption must have been greater.

The basalt varies much in character: in some places it is a hard massive rock without any marked joints; elsewhere it occurs in large blocks approaching in form to regular polygons; occasionally it is columnar, and often it is merely an indurated black clay, with an unequal schistose cleavage, splitting into very irregular rhombs. It is usually compact, but frequently amygdaloidal or slightly crystalline; and these varieties commonly pass into each other. The best columns

of basalt are at the summit of Cabeça de Montachique to the north-west of Loures; some less perfect occur at the foot of a battery called Forte de San João das Maias, on the bank of the Tagus, near Oeiras.

The only beds which rest upon the basalt belong to the tertiary series; they cover its south-eastern edge, and were deposited after the cessation of the basaltic eruption. The position of the basalt with regard to the secondary formations, deserves particular attention. That part of the great deposit to the west of Loures, breaks the continuity of the secondary strata (see Pl. XIV. and Pl. XV. Sect. 6 and 8), both the red sandstone and Hippurite limestone being divided by it into two portions. The beds which lie to the northward of the basalt are nearly horizontal, and are usually overlaid by that rock; while on the southern side of the basalt, the red sandstone is elevated into bold steep hills, in which the beds dip to the S.E. at angles varying from 40° to 70°, and in one instance to 90°. The Hippurite limestone, resting upon the southern edge of this line of red sandstone, has partaken of the same movement, and dips in the same direction from 30° to 45°, the greatest elevation of both of these formations occuring in the narrow ridge of hills extending from Canessas towards Loures. The basalt also rests upon the southern foot of this elevated ridge of Hippurite limestone, and thence it reaches to the Tagus, the elevation of the limestone gradually diminishing, and the sheet of basalt thinning off to the southward, till, along the bank of the river, the basalt rests upon nearly horizontal beds of the limestone (see Coast Section 3), filling up hollows in the surface, and gradually diminishing in thickness till it is lost near Oeiras. On the north-west of Loures the basalt spreads over the Hippurite limestone (there inclined about 20°) in the same manner, and thins away toward the N.E. till it totally disappears without reaching the Tagus.

It is therefore evident, that the whole of this great mass of basalt was thrown up after the deposition of the last of the secondary and before that of the oldest of the tertiary formations, through a great cleft in the secondary rocks which extended westward from the site of the village of Loures; that the eruption of the basalt elevated the ridge of red sandstone and Hippurite limestone to the south of the cleft; and that the whole of the rest of the deposit of basalt, ranging N.E. toward Verdelha and southward to the mouth of the Tagus, flowed out through the narrow gorge behind Loures, and spread itself in all directions.

In no spot does the basalt appear to have passed the present line of the Tagus, and in some parts, as already stated, it has not even reached it, thinning away on the north near Verdelha, and at the entrance to Lisbon from Campolide.

The section in the cliff of Cascaes Bay (Pl. XV. Sect. 10) affords a good example of the disturbing power of basalt. About a quarter of a mile east of Cascaes a perpendicular wall of basalt, thirty feet

thick, rises from the beach to the height of twenty feet; and a few hundred yards farther two smaller basaltic dykes rise in a similar manner. The basalt can be seen only on the beach, as the dykes run inland, and are entirely covered by the red sandstones belonging to the upper division of that formation, constituting the cliffs with the adjacent country, and containing the sulphureous and lignite beds before described. The disturbance produced by the basalt is so great, that eleven considerable faults occur in the cliff within half a mile; and to the same cause must be attributed the greater dip of the strata of red sandstone in this district than to the westward of Cascaes. The line of elevation which begins at Cascaes Bay runs north-east to the steep ridge of hills already mentioned between Canessas and Loures, so that all the red sandstone between Cascaes and Loures is thrown up in the same direction, dipping to the S.E. From this it may be concluded, that the whole of that range of hills was elevated by one basaltic eruption; and although we cannot trace the basalt below the surface along the line, still, as it has burst through the strata at one extremity and upheaved them at the other, the whole must be attributed to one cause, and the dykes at Cascaes considered to belong to the same period as the basalt of the great eruption near Loures.

Between Loures and San Estevão das Galés a mass of basalt caps a hill of Hippurite limestone, the beds of which dip both from the north and south sides of the hill toward the centre. This is the only spot where such an irregularity is met with, and it may have been caused by a small eruption of basalt through the centre of the hill. In any case, the cap is of the same epoch as the basalt already described.

On the beach to the west of Cezimbra, some masses of basalt have been intruded between the beds of red sandstone, and may perhaps be of the same age as the above. They have greatly disturbed the strata of sandstone, but the form of the coast does not admit of the effects being well shown in a section. This is the only spot south of the Tagus, where I met with basalt.

To return to the north of the Tagus. Many hills of red sandstone to the north of the great eruption are capped with detached masses of basalt; several of which are marked upon the map, but there are probably many others. At Sobral and San Sebastião are two very large masses, and there are some near Chilleiros and Areas north of Cintra (Sect. 2 and 6). In all these cases, the basalt rests upon undisturbed beds of sandstone, and there is nothing to lead to the supposition, that the hills were the vents of eruption; still it would not be safe to consider the cappings as parts of the great sheet of basalt around Loures, and their origin and date must be left uncertain. One mass, about three miles N.W. of Cintra, and near Fontanellas, deserves separate mention. It appears to be of an older date than the red sandstone; and though there is no section showing the junction of the two rocks, yet, as far as I could observe, the beds of sandstone rest horizontally upon the basalt, which is of a more porphyritic character than is usual in this district.

Although I had innumerable opportunities of examining the junction of the subjacent rocks with the basalt, which rests in different places upon nearly every bed

of the red sandstone and Hippurite limestone, I could not find a single instance of the stratified rocks having been altered by it. The basalt invariably lies immediately upon the formation below, without the intervention of any foreign materials; except in a quarry on the west side of the valley of Alcantara, where a deposit, such as might have been formed by the rolling forward of the mass of basalt, occurs between that rock and the Hippurite limestone. The section is as follows:—

Hard compact basalt.	
Basaltic clay	10 feet.
Breccia of ferruginous clay, containing argillaceous pebbles apparently calcined	6 —
Rubble of marl and clay, containing angular fragments of limestone and calcined ferruginous pebbles	5 —
Limestone, quite unaltered.	

The beds of trap interstratified with the slate-clay around Cintra having been described, it is unnecessary to recur to them, except to repeat that they are much older than the great mass of Lisbon basalt, and contemporaneous with the formation of shale.

An eruption of trap-rock at the northern foot of the conical hill on which stands the Moorish castle of Cezimbra, has elevated the Espichel limestone and the red sandstone to a high angle. The rock is an amygdaloid, consisting principally of felspar and green earth. The limestone dips at 70° from the trap on the northern, eastern, and southern sides of the hill, and the red sandstone inclines in the same directions at angles varying from 45° to 60°. (See Sect. 12.)

The limestone, for the thickness of fifty feet above the trap, is more crystalline than usual. There is nothing to point out the period of the eruption.

Granitic Rocks.

(Pl. XIV. and Pl. XV. Sect. 1, 2, 4, 5 and 7.)

The range of hills which extends from Cintra to the Atlantic, consists of granitic rocks. Its greatest length from San Pedro to the lighthouse on Cape Rock is about seven, and its extreme width about four miles. The highest points are not 2000 feet above the sea, yet they possess all the picturesque character of alpine scenery.

The prevailing rock is granite, consisting of nearly equal proportions of quartz and felspar, with a little mica; but it sometimes contains magnetic iron-ore, disseminated in small grains. Along the whole chain, the central parts of the hills are formed of a coarse-grained granite, which splits into large irregular blocks; and the

outer portions of a soft fine-grained granite with a schistose cleavage. In some places the grain is so fine and the cleavage into rhombs so marked, that the rock might easily be mistaken for sandstone if we were not able to trace the passage into a granite presenting its usual characters. Near Cintra the thickness of this schistose granite is not great, but near the lighthouse it is more considerable, and its peculiarity of character more marked. Link*, in describing this neighbourhood, seems in doubt about its nature, and calls it granite passing into sandstone. On the road to the lighthouse are many instances of veins of the hard larger-grained granite in the schistose granite; but the varieties pass into one another, showing that they were all formed at the same time.

Toward the western end of the chain, sienitic and porphyritic rocks occur in several places; and the chapel of the Peninha stands upon the junction of a mass of decomposed felspar-porphyry with the granite. Near Atalaya, I picked up some loose specimens of handsome red porphyry in the bed of a torrent. There is no section of the relative positions of the granite, sienite and porphyry; but from all I could see, I consider them to have been formed contemporaneously.

The granite is in several places intersected by veins, particularly near the western end of the chain. Near Atalaya it is traversed by a very thin vein of granite quite distinct from the mass of the rock; and in a ravine near the same place two veins traverse the granite, one being horizontal, about two feet thick, and of a sienitic character, the other perpendicular and of less importance. Both these veins pass so gradually into the granite, that they must have been formed at the same period with it. Near Cintra I met with a specimen of granite intersected by several veins, some of them not thicker than a sheet of paper; and they are too thin to have been formed by an injection of granitic matter into a crack. Near the Peninha chapel thin veins of granite traverse the porphyry.

Faults and Dislocations.

Near Cintra. (Pl. XV. Sect. 1, 2, 4, 5 and 7.)

Few districts offer such good opportunities of studying the question of elevation as that of Cintra. The granite rises to the height of nearly 2000 feet in one mass of moderate extent and at a great distance from any similar rock, so that the effect which it has produced upon the position of the surrounding strata may be investigated as a single problem.

Sections 1, 2, 4, 5 and 7, show the position of the secondary formations on every side of the Cintra hills; each of them being drawn in a different direction from the granite as from a centre, so as to show

* Geol. und Min. Bemerkungen auf einer Reise durch das südwestliche Europa, p. 59.

the position of all the formations near the granite, both with reference to that rock and to each other. In Nos. 2 and 5, extending north from the granite, the three lowest formations, the San Pedro limestone, the shale, and the Espichel limestone are seen greatly elevated, and dipping from the granite at angles varying from 20° to 80°.

The coast being very rough, I could not trace Section 5 so far as the preceding one, but the two agree to the extent they can be compared. In these sections and in No. 4 all the beds of Espichel limestone have not been equally affected; and from some cause not apparent, there is another line of elevation parallel to that caused by the granite, which has raised some of the beds of limestone into a saddle.

In Sections 1 and 7, which show the south-east and south sides of the chain, the San Pedro limestone, shale, and Espichel limestone are also raised by the granite, dipping from it at angles varying from 30° to 70°, the angle always increasing as the bed approaches the granite. Around these two sides of the hills the disturbing forces have been fewer, and the elevation of the three formations is very regular.

Section No. 4, drawn from the palace at Cintra to the N.E., offers irregularities which require particular notice. The San Pedro limestone is raised into a saddle, and the slate-clay dips from it on both sides, abutting against the granite, below the palace. The form of the whole mass of granite being nearly triangular, the strata which rest upon it have two principal lines of strike, parallel to the northern and south-eastern edges of the granite range; these two lines meet at a sharp angle just below the town of Cintra, and at their point of intersection the beds are forced up into a saddle, accompanied by several minor dislocations, one of which is shown in Section 4.

As the sections round the granite agree in representing the three oldest formations as resting at high inclinations upon that rock, we must conclude, that the granite was elevated to its present position after the deposition of the Espichel limestone, the newest of those formations.

Let us now examine the question with regard to the next formation, the red sandstone. Section 2 represents the sandstone resting nearly horizontally upon the elevated beds of Espichel limestone, and the want of conformity is the more apparent, as the sandstone rests upon the basset edges of the limestone, and dips in a contrary direction. There is also a want of conformity between the same beds on the south side of the Cintra chain. These two sections prove conclusively, that the sandstone was deposited after the elevation of the rocks below it, and after the granite had assumed its present height. There are, however, other sections bearing upon the case; in No. 4, the beds of sandstone are almost conformable with the uppermost beds of the limestone, but the beds of both rocks are so nearly horizontal, that no argument can be drawn from them. In Sections No. 1 and 7 there is also a conformity between these two formations, the sandstone dipping from the granite at angles of 20° and 30°. This seems to militate against the conclusion just drawn; but the map shows, that these sections cross that ridge of sandstone hills extending from Cascaes to Loures, which has been proved to have been raised at a later period by the basalt; and their inclined position is thus accounted for without reference to the eruption of the granite. We may therefore assume that the granite-hills of Cintra were elevated to their present position between the formation of the Espichel limestone and that of the red sandstone. The change produced by the granite upon the limestone in contact with it, has been already described at p. 123.

Disturbance of the Strata between Palmella and Cape Espichel. (Pl. XV. Sect. 1, 9, 11 to 13.)

The country between these two places forms so distinct a geological district, that its numerous disturbances deserve to be described apart. Sections 9, 11, 12 and 13, are drawn nearly parallel to one another across this district, to illustrate the dislocations of the strata, by exhibiting all the positions in which the beds lie with respect to each other, and they show that there have been considerable elevations at four distinct periods at least.

1st. The unconformable manner in which the Espichel limestone rests upon the older red conglomerate, shows that the latter had been elevated before the deposition of the former. (Section 13.)

2ndly. The position of the red sandstone upon the older rocks (Sections 9, 11 and 13), proves that these were again elevated after the deposition of the Espichel limestone.

3rdly. The position of the Almada beds upon the red sandstone at the end of the Serra de San Luiz (Sect. 1), shows that the sandstone had been much elevated before the tertiary period.

Lastly. The tertiary Almada beds have been much elevated all round the older chains; their usual dip being about 30°, but at Palmella it is 50° (Sec. 9), and at the foot of the Serra de Vizo nearly 80° (Sec. 13).

The forces which elevated this district acted at each period in the same direction along an anticlinal line ranging S.S.E. from the castle of Palmella. A considerable fault, crossing the red sandstone between Cezimbra and Cabo de Ayres, forms the western limit of these elevations, and has divided the neighbourhood of Cezimbra into two districts of disturbance. The dislocating agents are not visible on the east of the fault, but to the westward the trap-rock described at p. 127 rises at the northern foot of the castle of Cezimbra, elevating the Espichel limestone and the red sandstone to a great angle (Section 12). From this spot to Cape Espichel the same formations continue to dip highly to the north; and from the position of the beds, it is probable, that some other eruptive rocks may be found at the foot of the cliffs west of Cezimbra, which I had not time to visit. On the beach on the west side of Cezimbra are some large blocks of sienite, which could not have come from far, and which were probably derived from the foot of the cliffs further on.

All these disturbing forces had ceased to act before the deposition of the upper tertiary sand which was deposited when all the other strata formed a surface similar to that we now see; the only alteration which has affected this formation being that which has raised it above the level of the sea without breaking its original horizontality.

Superficial Detritus.

The valleys near Lisbon are often lined with detritus washed down from the hills inclosing them, but I did not see any of those accumulations of foreign materials which we have been accustomed to call diluvium. Some of the limestone hills, especially about Bellas and Loures, have been very much channeled by water, and the top of one hill near the latter village is covered by isolated rocks, several feet high, of limestone still remaining *in situ*, but worn into rounded masses separated by deep channels. This may have taken place during the tertiary period, for there is no evidence that the district has been washed over, since the deposition of the tertiary formations, by any of those immense bodies of water of which we see so many traces in other countries.

APPENDIX.

On the Earthquake of 1755.

The physical effects of the great earthquake which destroyed part of Lisbon in 1755, have been very much exaggerated. The accounts of the great loss of life and destruction of property carry away the imagination, and lead us to think the geological action of the earthquake much greater than it really was. A large part of the present town consists of houses erected before the catastrophe, and of

the buildings destroyed, nearly as many were consumed by fire as overthrown by the shocks.

With the help of a very detailed account of each parish in Lisbon, published in 1758 by João Baptista de Castro, in the fifth volume of his 'Mappa de Portugal', and after a careful examination of the age of the principal buildings, I coloured a map of Lisbon in such a manner as to show the violence of the earthquake in the different parts of the town. No mischief whatever was done westward of a line which nearly corresponds with the Rua de San Bento. J. B. de Castro's assertion of this fact is very decisive, and there are two structures further west which would have been the first to have fallen, had the shock been as violent in that district as in the centre of the town: the great bridge of the aqueduct over the valley of Alcantara was not injured, a prevalent tradition also says, that only one stone of the parapet was thrown down by the earthquake; and the beautiful gothic church of St. Jerome at Belem, with its lofty stone roof supported upon very slender columns, remains uninjured.

The principal force of the earthquake was confined to the valley reaching from the public walk to the Terreiro do Paço and to the low streets which run along the side of the river from the corn-market as far as Boa Vista; the lower parts of the adjoining hills also suffered considerably; but beyond these limits, the damage done was not great: the quarter of Alfama, behind the castle, consists entirely of old houses, and the northern suburbs suffered but little.

I next inquired whether the district thus selected by the earthquake corresponded with the distribution of the strata on which the city stands. It is never easy to determine the exact boundaries of strata beneath a town; still the irregular, unfinished manner in which Lisbon is built, the unevenness of the ground, and a number of drains which were opened in different parts of the town, enabled me to form a tolerable geological survey. The west end of the city stands upon the Hippurite limestone, and the rest upon the Almada beds, which are nearly horizontal, and overlie the Hippurite limestone unconformably, so that the lower tertiary beds are not brought up to the surface at the junction of the two formations; all the higher parts of the town stand upon the upper Almada beds, and the lower streets upon the blue clay, which has been left exposed by the denudation of the upper beds.

On comparing my two maps of the city, I found a very striking resemblance, which I had not expected. The greatest force of the earthquake was confined to the area of the blue clay, and not one of the buildings which stood upon that bed escaped; those upon the slopes of the hills standing upon the beds immediately above the clay, suffered very severely, and the whole of the tertiary strata were more or less affected by the shocks. On the contrary, all the buildings erected upon the Hippurite limestone and the basalt escaped entirely; the line at which

the force of the earthquake ceased to be destructive, corresponding exactly with the boundary of the tertiary beds.

The earthquake did not destroy many buildings in the neighbourhood of Lisbon, but I could not find any account of the extent of the damage done; yet the little evidence I obtained, corresponds with that derived from the interior of the town. Saccavem, which stands upon the upper Almada beds, is said to have suffered considerably; but Queluz and Odivellas, built upon basalt, were not damaged. The bridge of the aqueduct, already mentioned as having escaped, stands across the junction of the basalt and the Hippurite limestone. It is therefore evident, that the violence of the earthquake was quite unconnected with the presence of basalt, with which Link (*loc. cit.* p. 68) and others have attempted to connect it.

Postscript, *September 15th*, 1840.

Since the preceding paper was laid before the Society, a more complete examination of the fossils has altered some of the views I at first entertained as to the age of the secondary deposits*; I had thought the following to be equivalents:

Hippurite limestone	Cretaceous series.
Red sandstone formation	Oolitic series.
Espichel limestone	Lias.

I am now disposed to consider all those three formations referrible to the cretaceous series of the North of Europe; following in this respect the opinion of MM. Boblaye and Virlet, who refer to that series a similar succession of beds observed by them in the Morea, although I cannot quite agree with those gentlemen in identifying the separate beds of the South with individual deposits of the North of Europe.

Hippurite Limestone: as this is a calcareous deposit forming the upper part of the cretaceous series, and nearly all its shells belong to the chalk and green sand, it may be taken as the equivalent of our chalk.

Red Sandstone Formation: this contains shells of our green sand mixed with others of the oolites. MM. Boblaye and Virlet describe, in the Morea,

Grès vert supérieur,
Calcaires lithographiques,
Grès vert inférieur;

and in the South of Spain Colonel Silvertop mentions three formations corresponding with the above divisions; thus in the Morea and in Andalusia the cal-

* Proceedings, vol. iii. page 34.

careous beds assume a more independent character than in Portugal, where I could draw no line between them and the beds above and below.

Espichel Limestone: the *Grès vert inférieur* of the Morea is succeeded, according to the authors above quoted, by blue limestone with beds of argillaceous marl, evidently the equivalents of this Espichel limestone. In both countries, it contains an union of species of the green sand and the coral-rag; yet the evidence of its connexion with the cretaceous series is very great; for *Trigonia scabra*, considered by M. Deshayes as one of the most characteristic shells of the green sand, was found in the lowest beds of this formation, as well as *Exogyra plicata*, the most abundant shell of the Hippurite limestone. Were this the only bed of the series containing shells of our oolites, it might be referred to the Neocomian epoch, and the comparison of the beds of the red sandstone formation with the upper and lower green sands might be admitted; but as all the Portuguese deposits from the Hippurite limestone to the Espichel limestone, contain some shells of the coral-rag, I think it safer to refer the whole to the cretaceous epoch, without attempting to identify the beds separately.

I have not sufficient information about the strata below the Espichel limestone, to attempt to compare them with the English formations.

VIII.—*Remarks on some Fossil and Recent Shells, collected by Captain Bayfield, R.N., in Canada.*

By CHARLES LYELL, Esq., V.P.G.S., F.R.S.

[Read April 24, 1839.]

PLATE XVI.

SEVERAL eminent conchologists have observed, that in some strata of the English crag there are certain species and genera of shells which seem to indicate a somewhat colder climate than that which now prevails in our latitudes; and it has been supposed that a similar inference may be deduced with still greater certainty from the abundant occurrence of many arctic species in the most modern of the marine Newer Pliocene strata of Scotland and Ireland. These opinions induce me to offer some remarks on a collection of fossil and recent shells which have lately been sent to me from Canada by Captain Bayfield, who procured the fossils from the newest tertiary deposits bordering the Gulf of St. Lawrence, and the recent Testacea from the Gulf itself.

The shells were found principally at Beauport, on the east bank of a river of that name, which enters the St. Lawrence on its northern side about two miles below Quebec, in lat. 47°; but the same formation is traced in the valley of the St. Charles and many other places, at heights varying from 30 to 300 feet above the Gulf.

"The strata," says Captain Bayfield, "are of sand, gravel, and stiff blue clay, similar to deposits at present forming lower down, as well as higher up, the St. Lawrence. They fill a valley previously formed in an ancient horizontal limestone, containing *Trilobites, Orthocerata,* &c. Angular fragments of this limestone, and a *Trilobite* washed out of its matrix, were found amongst the modern shells. The upper stratum of sand is nearly 100 feet above the St. Lawrence, and is almost exclusively composed of bivalves. The strata have been traced a mile up the valley on the east bank of the Beauport river, the ancient limestone forming the west bank. Similar shells were also met with, at a still higher elevation, on the north side of the valley of the St. Charles, about three miles from Beauport. In these and all other localities of the same formation, the lowest strata usually consist of clay, and the uppermost of sand and clay mixed. It is in these last that the shells are abundant, being rare in the stiff blue clay.

"The tertiary strata," says Captain Bayfield, "contain numerous boulders of primary rocks, which occur at different levels, not resting upon each other, but as if they had been dropped there at widely different times during a long period in which a quiet deposition of clay, sand and gravel had been going on, and in which the various genera of Testacea had lived and died. Of course some of the shells are broken, and some of the valves separate, as is found in the bottom of the present sea; but many have both valves together as they lived, although they separate when taken up, because the ligament no longer exists. But all idea of these shells, together with the clay, sand, gravel and boulders having been drifted together into their present position by a violent current or rush of water, must be given up at once when I state the fact, that the *Terebratula psittacea*, which you know are so fragile that the smallest stones would be sufficient to destroy them if carried along even with a moderate degree of violence by moving water, are found with their valves together, and their long and brittle teeth entire as when they were living. The whole of the facts lead me to infer, that these numerous erratic blocks have been carried by ice, and dropped from time to time on the bed of the tertiary sea."—(*Extract from letter, dated* 11*th November*, 1835.)

Deposits containing the same fossil shells were also found at Port Neuf, forty miles above Quebec, in terraces of clay and sand, which rise to different levels above the St. Lawrence, and parallel to its course. They occur at heights varying from 50 to 200 feet above the river.

When I first received these fossil shells from Captain Bayfield, I was struck with their great resemblance to those which I had collected at Uddevalla, in Sweden; and this similarity was confirmed by Dr. Beck, after a minute examination. The *Saxicava rugosa*, so predominant at Uddevalla, is particularly mentioned by Captain Bayfield as the most numerous shell in all the deposits, and the *Natica clausa* and *Pecten islandicus* are very common, as at Uddevalla. On the other hand, the fossils at Beauport, considered as a whole, by no means agreed with the marine shells now inhabiting the Gulf of St. Lawrence. For the names of most of the Beauport shells in the following list, I am indebted to Dr. Beck, who determined, in 1836, all that I had then received.

1. *List of Fossil Shells from Beauport, near Quebec.*

1. *Tritonium Anglicanum*, a Newfoundland and Greenland species, or variety, according to some authors, of *Buccinum undatum*. See Pl. XVI. figs. 1, 2. No. 2 has the ridges less prominent.
2. *T. fornicatum*, Fabric. Fauna Gröenlandica, 399. It is the *Fusus carinatus*, Lamk. (See Pl. XVI. fig. 3.) Recent from Bic, Canada. Dr. Lovén has it recent from Finmark. *T. fornicatum* is considered by most authors as a variety of *Fusus despectus*, a Greenland species or variety, but which seems also undistinguishable from one now recent at Cork, in Ireland, and which is also found fossil at Dalmuir, in the Firth of Clyde.
3. *Natica clausa* (*N. septentrionalis*, Beck), Brod. and Sow., Zoological Journal, vol. iv. p. 372. Beechey's Appendix, Pl. XXXIV. fig. 3, and Pl. XXXVII. fig. 6, a species still living in Greenland, the North Sea, and North America. Very common at Uddevalla.
4. *Scalaria borealis*, Philosophical Transactions, 1835, Pl. II. figs. 11, 12. Living in Greenland seas, according to Beck.
5. *S. Gröenlandica*, var.? (Pl. XVI. fig. 4.) Dr. Beck was of opinion that this might be the same as

the recent shells figured by Chemnitz, and now living in the Greenland seas, but if so the fossil species constitute a marked variety, the varices being more slender and more lamellar at their posterior ends.

6. *Mya truncata* (Pl. XVII. fig. 5, 6.). Shell shorter than the common form, and the posterior truncation oblique, and inclined to the basal margin, and with a smaller sinus in the muscular impression. This variety is identical with one found fossil by Mr. Smith in Bute, and considered as an extinct species, but I have the same recent from the St. Lawrence, and intermediate varieties between it and the normal form of *M. truncata*.
7. *Mya arenaria*. One valve; the same is also recent in the Gulf of St. Lawrence. I have not seen this shell, but it was identified by Captain Bayfield, who sent me recent shells from the same.
8. *Saxicava rugosa*. Port Neuf. The two varieties of this species which prevail at Uddevalla are also common at Beauport. One of these I have figured in the Phil. Trans. 1835; Pl. II., the other with the umbones more central is figured in the annexed Plate XVII., fig. 7. There are intermediate ones between these two.
9. *Tellina gröenlandica*, Beck. (Pl. XVII., fig. 8 a., 8 b.). Also living in the Gulf of St. Lawrence; and at the Icy Cape, according to Mr. G. Sowerby.
10. *Tellina calcarea*, var.? Wahlenberg, p. 36. (*T. proxima*, Brown, *T. triangularis*, Phil. Trans. 1835; Pl. XVII., fig. 9, 10, 11.). The fossil from Canada differs slightly from that which is so common at Uddevalla, and from the same which occurs fossil at Bute, both in its larger size and in the form of the palleal impression, which does not extend so far forward. See Pl. XVII figs. 9, 10. I have a recent one from the Norway seas identical with the Uddevalla variety.
11. *Nucula*. One broken valve which I have not seen.
12. *Mytilus edulis*.
13. *Pecten islandicus*. Living in the North Sea; not known as British, but occurring in the newer Pliocene beds in Scotland.
14. *Terebratula psittacea*, var. Scarcely showing any of those traces of longitudinal striæ which are common in the living species from Labrador, but considered by Dr. Beck and Mr. Sowerby to be the same as the recent species, which has a wide geographical range, occurring in Greenland and the Feroe Islands, and half-way between these islands and Denmark.
15. *Balanus Uddevallensis*, Lin. (*B. scoticus*). Same as the large Balanus found fossil at Uddevalla, and not distinguishable from *B. scoticus* (genus *Chirona* of Gray), a British species found in the German Ocean off Scarborough. The Uddevalla and Beauport specimens are similarly striated externally. (See Phil. Trans. 1835; p. 37.)
16. *Balanus miser*, Gould, (Pl. XVII., fig. 12 a.,) f. 12 b. is a single valve of an elongated variety.
17. *Echinus*. Fragments apparently identical with a living species found in the Gulf of St. Lawrence.

Although the fossil species amount to no more than sixteen, the number of individuals examined was very great, affording in this respect a striking analogy to the deposits near Uddevalla in Sweden. This limited variety of species, so different from that observed in the present fauna of the neighbouring gulf, seems to favour the hypothesis that the climate was formerly much colder.

For the sake of comparison I subjoin a list of the recent marine shells of the Gulf of St. Lawrence, forwarded to me by Capt. Bayfield, in the naming of which I have been assisted by Dr. Beck and Mr. George Sowerby.

2. *List of Recent Marine Shells collected in the Gulf of St. Lawrence.*

1. Pholas crispata.
2. Glycimeris siliqua.
3. Solen Americanus.
4. Solenocurtus nitidus, *Say*.
5. ——— costatus, *Say*.
6. Mya truncata.
7. —— arenaria.
8. Pandora trilineata, *Say*.
9. Anatina Leana, *Conrad*. (Cochlodesma Leana, *Couthouy*, Boston Journ.) Rare in Gulf of St. Lawrence.
10. Mactra ovalis, *Gould*. (M. similis, *Gray*, MS. in Brit. Mus., Beechey Zool. T. xliv., f. 8.)
11. Mactra solidissima, *Say*. (M. giganteum, *Chemnitz*.)
12. Mesodesma Jauresii. (*Joannis* in Mag. de Zool. t. liv. 1834.)
13. Saxicava rugosa, both the varieties mentioned in the preceding list of fossil shells.
14. Petricola pholadiformis.
15. Tellina gröenlandica, *Beck*. (Sanguinolaria fusca of American authors.)
16. Venus mercenaria.
17. Astarte borealis, *var*.
18. ——— sulcata.
19. ———, probably N.S.
20. ———, allied to compressa, perhaps identical.
21. Cardium gröenlandicum, *Lamk*. (Aphrodite columba, *Lea*; Amer. Phil. Trans.)
22. Cardium islandicum.
23. Nucula myalis, *Couthouy*.
24. ——— concentrica, *Say*.
25. Mytilus edulis.
26. Modiola glandula, *Gould*. Rare in the St. Lawrence.
27. ——— plicatula?
28. ——— papuana.
29. Pecten islandicus.
30. ——— magellanicus, *Lamk*.
31. Ostrea Americana.
32. Balanus costatus.
33. ——— miser.
34. Buccinum undatum.
35. ——— cyaneum, *Brug*. (Tritonium cyaneum, *Beck*.) Query *var*. of B. undatum.
36. ———, N.S., allied to B. undatum.
37. ——— obsoletum. (Nassa obsoleta, *Say*.)
38. Nassa trivittata, *Say*.
39. Purpura lapillus, *var*.
40. Rostellaria occidentalis. (Aporrhais occidentalis.)
41. Fusus carinatus, *Lamk*.
42. ——, allied to or identical with recent species from Icy Cape.
43. ——, N.S., allied to F. turricula.
44. ——, N.S., also allied to F. turricula. (Murex turricula, *Mont*.)
45. Natica ampullaria, *Lamk*. (N. heros, *Say*.)
46. Turritella erosa, *Couthouy*.
47. Littorina vestita. (Turbo vestitus, *Say*.)
48. ——— palliata. (Turbo palliatus, *Say*.)
49. Lacuna vincta, *Turton*.
50. Margarita striata.
51. Crepidula fornicata.
52. Patella testudinalis. (Lottia, *Gray*.)

The torrents and rivers, says Capt. Bayfield, which flow into the St. Lawrence sweep down annually into that estuary great numbers of fossil shells from the modern tertiary deposits, so that they are mingled with living shells, and thus the productions of two periods are confounded together. Of this intermixture there appear abundant examples in a collection of shells dredged up by Capt. Bayfield from the mud at the bottom of the Gulf of St. Lawrence, near the island of Bic, where the water was between fifteen and sixteen fathoms deep. Among these the recent shells may generally be distinguished by retaining their colour, animal matter, or ligaments. It is more difficult to feel sure respecting those which have been exclusively derived from the tertiary deposits, but I have little doubt that to this number belong several specimens of the *Balanus Uddevallensis*, (fifteen of list No. 1.) and a *Fusus*, nearly allied to *F. lamellosus*, Lam., a species now living at Icy Cape, N. lat. 70°, and common at Uddevalla*. Both of these shells have been

* Phil. Trans., 1835, p. 37, where it is called *Rumphius*, misprint for *F. Bamfius*.

dredged up at Bic, in the same state as the Beauport fossils, but none of those sent to me were in the state of recent shells.

The newer Pliocene fossils therefore of Canada, so far as they have been hitherto examined, belong to species which either range in a living state from the Gulf of St. Lawrence to the borders of the north polar circle, or are now only known in high northern latitudes, as in the seas of Greenland, Iceland, and Norway, or agree with varieties or species found in the newer Pliocene deposits of Scotland and Sweden. On the other hand, many of the living species of shells now most conspicuous from their size or abundance in the Gulf of St. Lawrence are wanting in the collection of fossils hitherto obtained, as for example, *Mactra solidissima*, *Mesodesma Jauresii*, *Purpura Lapillus*, var., *Natica Heros*, *Rostellaria occidentalis*, and several others.

It would doubtless be rash to insist positively on any general conclusions which we may be tempted to draw from so small a number of fossil shells as those hitherto procured in Canada, but judging from them alone, they approach more nearly to the fossils of the most modern deposits of northern Europe than do the actual faunas of Europe and America in corresponding latitudes. The number of testacea indeed hitherto regarded as common to the opposite sides of the Atlantic is very small. Eleven only were known to Dr. Beck in 1836, and Mr. George Sowerby was able to add no more than four or five after a recent comparison of a large collection of shells of North America with those of Europe; and the fifty-two recent shells obtained by Capt. Bayfield from the St. Lawrence have only contributed one more to the number, namely, *Cardium islandicum*, which inhabits the northern parts of the German Ocean. Capt. Bayfield informs me that he also discovered the *Cardium islandicum* fossil at Port Neuf, although in too disintegrated a state to be preserved.

As the climate of Canada is now excessive, it is natural that we should find in the Gulf of St. Lawrence many northern and arctic species, and no mixture of tropical forms, for these last cannot resist severe cold, although we know from the analogy of the southern hemisphere that they can extend far toward polar latitudes, dispensing with a high temperature in summer provided the winters be mild.

It is very probable, therefore, that in the period immediately antecedent to the present the climate of Canada was even more excessive than it is now, and that the shells resembled still more closely that small assemblage now found in high northern latitudes. This extreme cold may have coincided with the era of the principal transportation of erratic blocks, which have reached the 36° 30′ degree of latitude in North America*.

* Darwin, Journal of Travels in South America, in Voyage of H. M. S. Beagle, Appendix, p. 614, who cites Rogers.

It is evident from the manner in which large fragments of rock are irregularly interspersed among the shelly strata near Quebec, as described by Capt. Bayfield, that when these deposits were taking place the transportation of blocks by ice was going on continually, as at the present moment, in the St. Lawrence.

I have mentioned that many of the testacea which now inhabit the Gulf of St. Lawrence, lat. 48° N., and some others which are found fossil in the Beauport beds, are of the same species which now live in the Northern Ocean between the latitudes 60° and 75° N. Perhaps the constant melting of ice in the Gulf may have some influence in promoting the range of northern species by cooling the waters to a temperature below that of the air in summer. This effect may be produced not only by the great quantity of ice which is drifted in the spring from Baffin's Bay along the coast of Labrador and then through the Straits of Belle Isle into the Gulf of St. Lawrence, but also by the ice which descends the St. Lawrence itself. This cause may help to assimilate the temperature of the sea in Canada at a certain depth to that which belongs to it nearer the surface much farther north. The wide distribution of species alluded to may be favoured, not only by the direction of the great current which runs from Baffin's Bay southward, and which may drift along the eggs of mollusca, or their young, but also by the ice islands themselves, which are continually stranding on all parts of the coasts and again leaving the same, so that they may carry away with them not only mud, sand and blocks of granite, but also many entire and living shells.

In a letter, dated Nov. 1837, Capt. Bayfield says, " Last spring I watched the ice of Lake St. Peter, which takes two or three days to pass Quebec every spring, and had the pleasure to observe several boulders of considerable size, and many small stones, sand, earth, reeds, and plants on their way down the river, drifting along at a rate measured by the excess of every ebb tide over the preceding flood. The latter flows $4\frac{3}{4}$ hours at the rate of three knots, the former about $7\frac{1}{2}$ hours at four knots. Any boulders and other matters which are thus transported are liable to be dropped, at various points along the bed of the river, as the ice gives way to the increasing temperature of the air and water in the spring of the year. The fresh-water shells, which are often found washed up on the beaches, are doubtless carried low down the estuary in this way, being frozen into the mass of ice which forms on the shoals where they abound."

I have spoken of the deposit at Beauport and other places as belonging to the most modern tertiary or newer Pliocene period, and the only doubt which can be entertained as to its age is, whether it ought rather to be referred to the post-tertiary era, or to that in which all the shells are identical with species now existing. As the number hitherto obtained amounts to no more than sixteen, it would be premature to offer a positive opinion on this subject. Some conchologists would

probably incline to believe, that two shells of the above list which I have figured, *Scalaria gröenlandica* and *Tellina calcarea*, ought to be regarded as new and distinct species. In every case it seems clear that when the Beauport fossils were deposited the testaceous fauna approached more nearly to that now established in the arctic regions, than to that which characterizes at present the Gulf of St. Lawrence; and the small number of species, amid so great a profusion of individuals, affords, as before hinted, a strong argument in favour of the greater severity of the climate at an epoch immediately antecedent to the present. Nor should we be surprised at discovering that there have been oscillations of climate in times which are, comparatively speaking, of recent date, when we see proofs of considerable geographical changes within the same epoch, namely, those which in Canada have converted sea into land, and raised the shelly strata above described to the height of 300 feet.

I think it probable that this extreme climate prevailed at once in the north of Europe and in Canada at the time when the shelly strata of Scandinavia and the basin of the St. Lawrence were simultaneously accumulated, and that there was then a more close resemblance between the shells living in these latitudes, on either side of the Atlantic, than we find at the present epoch.

Description of Plate XVII.

Fig. 1, 2. *Tritonium anglicanum.* (*Buccinum undatum*?) Fig. 2 has the ridges less prominent.

Fig. 3. *T. fornicatum*, Fab. (*Fusus carinatus*, Lamk.)

Fig. 4. *Scalaria Gröenlandica*, var.?

Fig. 5, 6. *Mya truncata.*

Fig. 7. *Saxicava rugosa*, variety having the umbones more central.

Fig. 8. *Tellina Gröenlandica*, Beck. Fig. 8. a. shows the outer, and 8. b. the inner side.

Fig. 9, 10, 11. *Tellina calcarea*, var.? Wahlenberg. (*T. proxima*, Brown, *T. triangularis*, Phil. Trans. 1835, p. 36.)

Fig. 12. *Balanus miser*, Gould. 12 a. shows the ordinary form; 12. b. represents a single valve of an elongated variety.

The above eight species found fossil at Beauport, Canada.

IX.—*On the Distribution of Organic Remains in the Strata of the Yorkshire Coast, from the Upper Sandstone to the Oxford Clay inclusive.*

By W. C. WILLIAMSON, Esq.

[Read May 9, 1838.]

IN two former papers read before the Members of the Geological Society*, I described the distribution of fossil remains in the strata from the Lower Lias to the Bath Oolite inclusive. I now continue the series in the same ascending order.

Next in succession, after the Bath Oolite, is the

Upper Sandstone and Shale of Phillips.

These sandstones and shales vary so greatly, that it would be impossible to form any detailed section equally applicable to all points of the coast. This however becomes of less importance, since the removal of the fossiliferous shales of Gristhorpe Bay from the stratum under notice to the Great Oolite has left few fossils remaining to the upper sandstone †.

This formation first appears at Gristhorpe Bay, but it is there of comparatively inconsiderable thickness. The sandstones forming the point and southern side of Ewe Nab seem to correspond with the lower portion of the Gristhorpe deposits supposed to be enclosed within the upper beds of the Bath oolite; but on the north side of the point, the same fault which so suddenly terminates the Crinoidal ironstone, as described in my last paper‡, also cuts off these sandstones. This fault has a downcast throw of at least 200 feet, for we find the beds of the true *upper sandstone and shale* at the low water mark; whilst the blue clays, corresponding with those of Oxford, are on the same level with the upper portions of the Bath oolite, the intervening rocks being exhibited on the scar. From this point the true carboniferous sandstones rise towards White Nab, where they overlie the argillaceous shelly beds constituting the top of the Bath oolite, as described in my last memoir (p. 234), and continue in the form of a series of variable sand-

* See vol. v. p. 223. † *Ibid.*, p. 234.

‡ *Ibid.*, p. 234, where, by mistake, the fault is said to be on the south side of the point.

stones to the Spa at Scarborough. On the northern side of Scarborough Castle the upper beds of the stratum dip under the cornbrash, and consist chiefly of soft yellow sandstones, but near Scalby Beck a mass of soft blue clay intervenes; below this a variable series of sandstones and clays occupies the remainder of the coast to Cloughton Wyke, where the lower beds again repose on the Bath oolite. After capping the cliffs of Stainton Dale, they do not reoccur on the sea-coast.

These beds are certainly much thinner to the south than to the north of Scarborough; and from their changeable character, and the comparative absence of organic remains, but three divisions can be established, and these perhaps not very distinctly. Mr. Phillips, in his 'Geology of Yorkshire,' vol. i. p. 40, remarks, "the lower part consists chiefly of thick irregular strata of sandstones. Above is a thick deposit of dark- and light-coloured shale, with alternations of thin sandstones." This was written under the impression that the argillaceous deposits of Gristhorpe were to be considered as the top of this series. A thick mass of rather compact, light yellow sandstones reposes on the Bath oolite; then a series of shales, occasionally changing into soft clays, and these are surmounted by another series of yellow sandstones much thinner than the lower group.

The two principal localities for fossils are on the north side of Scalby Beck (near Scarborough), where, not far from the top of the lower division of sandstones, the beautiful *Cyclopteris digitata* of Lindley and Hutton (not of Brongniart) occurs; and still lower in the series, in Burniston Bay, a layer of ferruginous sandstone contains *Pecopteris Murrayana*, *Otopteris obtusa*, and an unfigured *Carpolithes*; a considerable quantity of imperfectly preserved fossil wood occurs north of Scarborough Castle. In the lowest beds, south of the Spa, I have observed traces of Cycadean and Equisetiform plants, as well as quantities of carbonized wood in small fragments. The ironstones scattered through the stratum generally contain veins of the Scarbroite of Harcourt*. There is no doubt that further investigation will materially increase this list of fossils. I have found the *Cyclopteris* in the lower sandstone and shale, whilst Brongniart's species, which is less deeply lobed and more palmate, seems confined to the deposits of Gristhorpe Bay. The *Otopteris* I have not seen from any other stratum; but so little is yet known of the fossil remains of these sandstones, that the above cannot be called characteristic.

Cornbrash.

This formation first rises from the foot of Gristhorpe cliff, at "Pudding Hole." By the fault at Redcliff it is thrown down to the shore. Near the northern extremity of Cayton Bay it is again observed for a limited extent, but it is soon lost

* Annals of Philosophy, March 1829.

under the thick diluvial covering. The fault at Ewe Nab has thrown the cornbrash, on its northern side, half-way down to the low water mark, where a small portion is exposed, not observed until recently*. Slight traces of it exist in the cliffs above the Spa at Scarborough, and it appears, for the last time, under the Castle Hill. It may also occur in some of the high cliffs south of Cloughton Wyke, as I have found its fossils amongst the rocks fallen from above.

The cornbrash seldom averages more than five feet in thickness, consequently few subdivisions can be expected. At Cayton Bay it is about four feet, and reposes on a blue clay varying from three inches to four feet. The following is a general ascending section:

Blue clay	3 inches to 4 feet.
Hard ironshot rock	2 feet.
Softer rock, sometimes ironshot	2 ——
Fissile oolite, easily decomposed by the atmosphere	6 inches.

At Ewe Nab it is less ironshot. At Cayton Bay the clay yields heads and claws of a small Astacus? enclosed in round argillaceous nodules, and occasionally a rather large bivalve not unlike an Unio, also a small Belemnite, not yet described. The upper fissile portion of the cornbrash contains chiefly *Terebratula ovoides*, *T. obsoleta*, *Ostrea edulina* and *O. Marshii*. The greater number of the fossils however occur towards the middle of the bed. The following are the most abundant:

Clypeus orbicularis.
Mya literata.
Amphidesma decurtatum.
———— securiforme.
Cardium citrinoideum.
Trigonia clavellata.
Trigonia costata.
Unio peregrinus.
Plagiostoma rigidulum.
———— interstinctum.
Ostrea Marshii.
Ammonites Herveyi.

The following species also occur, but less abundantly:

Cidaris vagans, and another species.
Clypeus clunicularis.
Galerites depressus.
Serpula intestinalis.
Pholadomya Murchisoni.
———— ovalis.
Mya calceiformis.
Cardium dissimile.
Isocardia minima.
Modiola cuneata.
Lima rudis.
Pecten lens.
——— demissus.
——— inæquicostatus.
Melania vittata.
Trochus granulatus.
Terebra granulata.
Belemnites.
Ammonites terebratus.

* Two years ago I pointed out the necessity of its existence at this spot, when examining the fault and its effects, but from the thick covering of fallen rocks I could not then find it. It contains several new fossils.

In the lower, or ironshot portion of the rock only, I have met with

Sanguinolaria undulata.	Pinna cuneata.
Cucullea carinata (nobis).	Terebratula digona.

Hitherto, I believe, no remains of Saurians have been found in the cornbrash of Yorkshire; and of Crustacea (excepting those in the clay), portions only of two claws and one body, the latter probably the *A. rostratus*.

The following fossils I have not seen from any other stratum, and they are apparently characteristic of it, at least on the Yorkshire coast:

Plagiostoma rigidulum.	Terebra granulata.
Cucullea, new species.	Ammonites Herveyi.
Terebratula digona.	——— terebratus.
Melania vittata.	

The following species are found also in the Bath oolite:

Cidaris vagans.	Trigonia costata.
Pholadomya ovalis.	Unio peregrinus.
——— Murchisoni.	Plagiostoma interstinctum.
Mya literata.	Pinna cuneata.
Amphidesma decurtatum.	Ostrea Marshii.
——— securiforme.	Trochus granulatus.
Trigonia clavellata.	

The following are also obtained in the coralline oolite:

Pholadomya ovalis.	Pecten inæquicostatus.
Mya literata.	——— lens.
Trigonia clavellata.	Ostrea Marshii.
Modiola cuneata.	Terebratula obsoleta.
Lima rudis.	Astacus rostratus?

Kelloways Rock.

This is best exposed at Gristhorpe, Cayton Bay, and Scarborough Castle Cliff. At the latter place it presents the following ascending section:

(*a.*) Soft variable beds, yellow at the lower, and light green towards the upper portions; occasionally tinged with peroxide of iron ..... 35 feet.
(*b.*) Hard ironstone ..... 5 —

The ironstone (*b.*) is full of fossils, but owing to its hardness they are extracted with difficulty. They chiefly consist of

Lucina lirata.	Ammonites Calloviensis, var. Gulielmi.
Gryphæa dilatata, var. β.	——— sublævis.
Ostrea Marshii.	——— Kœnigi.
Belemnites abbreviatus.	——— Sutherlandeæ.
——— tornatilis.	——— flexicostatus.
Ammonites Calloviensis.	

The great bulk of the fossils, however, is found towards the upper portion of the main mass of the stratum. The following species are the most abundant:

Dicotyledonous? wood.
Amphidesma recurvum.
Lucina lirata.
Avicula Braamburiensis.
——— expansa.
Gryphæa dilatata, var. β.
Ostrea Marshii.
Terebratula ornithocephala.
——— socialis.
Turbo sulcostomus.
Belemnites abbreviatus.
Belemnites tornatilis.
Ammonites flexicostatus.
——— sublævis.
——— gemmatus.
——— Calloviensis.
——— ———, var. Gulielmi.
——— perarmatus.
——— ichthyodorsus (nob.).
——— Gamma (nob.).
——— rotifer (nob.).
——— oblisus (nob.).

The following fossils also occur about the same position, but are less frequently met with:

Astacus rostratus.
Mya literata.
Cardium dissimile.
Trigonia costata.
——— clavellata.
Pecten fibrosus.
——— lens.
Ostrea undosa.
Cirrus depressus.
Trochus guttatus.
Rostellaria bispinosa.
Rostellaria bisulcata (nob.).
Nautilus hexagonus.
Ammonites Duncani.
——— athleta.
——— Gowerianus.
——— bifrons.
——— Kœnigi.
——— plicatilis.
Palatal bone of a fish.
Ichthyosaurus.
Plesiosaurus.

Of these, I have obtained from the cornbrash,—

Mya literata.
Cardium dissimile.
Trigonia costata.
Trigonia clavellata.
Pecten lens.

The following species occur also in the coralline oolite:

Mya literata.
Amphidesma recurvum.
Lucina lirata.
Trigonia clavellata.
Avicula Braamburiensis.
Avicula expansa.
Pecten lens.
Ostrea Marshii.
Terebratula ornithocephala.
——— socialis.

The fossils of the Kelloways rock in general are highly characteristic. Few of the Ammonites have been met with in any other stratum; and so far as

my own observations extend, the following fossils appear to be confined to it in Yorkshire :

Gryphæa dilatata, var. β.	Cirrus depressus.
Turbo sulcostomus.	Belemnites tornatilis.
Trochus guttatus.	Nautilus hexagonus ? (see page 149, line 11.)

The last fossil has, I believe, been met with in another stratum, in the South of England. The palatal tooth of a fish apparently belongs to the genus *Orodus* or *Psammodus* (Agassiz), and closely resembles teeth from the forest marble. The Saurian remains chiefly consist of detached vertebræ of the Ichthyosaurus. In one instance I met with a large coracoid bone ; and a fine humerus of a Plesiosaurus was found at Hackness.

In Gristhorpe Bay the Kelloways rock is less arenaceous and ferruginous, and is sometimes slightly calcareous. The hard ironstone forming the top of the stratum at Scarborough is wanting at Hackness, its place being occupied by a blue clay containing numerous fossils, of which *Ammonites flexicostatus* is the most abundant. The lower part of the stratum is a fine-grained arenaceous rock, very soft when first removed from the quarry, but hardening rapidly on exposure to the atmosphere. It forms one of the finest building-stones in the east of Yorkshire, on account of the uniformity of its colour, its durability, or the ease with which it is worked. It appears to contain a greater abundance of *Ammonites sublævis* and *A. Sutherlandeæ* than at Scarborough. The thickness of this stratum varies considerably, being in some parts much greater, and in others less than thirty-five feet, the dimensions which it attains at Hackness. North of Scarborough Castle it is from sixty to seventy feet.

Oxford Clay.

Reposing on the Kelloways rock is the Oxford clay, generally averaging about 130 feet in thickness. It is not separable into divisions, consequently the task of directing the collector to the sites of its fossils becomes more difficult. The lower part of the formation is of a dark blue colour, argillaceous, and splits freely into small laminæ, or rather rhomboidal fragments. As we ascend in the section it gradually loses its argillaceous character, becoming more arenaceous, and is slightly tinged with yellow as it approaches the calcareous grit.

Organic remains are comparatively rare in the Oxford clay of Yorkshire, owing partly perhaps to so limited a portion of it being exposed to the action of the sea on the coast, whilst inland it is not laid open by pits. With one exception, the fossils seem to occur in the lower part of the formation ; and the portion immediately reposing upon the Kelloways rock seems to be characterized by the pre-

sence of *Belemnites abbreviatus* and *Gryphæa bullata*. A little above these, the great mass of fossils is met with. The following are the species which I have found in that position :

Serpula intestinalis.	Pecten, a smooth species.
Astarte lurida.	Belemnites gracilis.
——— carinata.	Ammonites Vernoni.
Avicula expansa.	——— cristatus.
Nucula nuda.	——— athleta.
——— elliptica.	——— oculatus.
Pinna mitis.	Teeth of a Squalus.

I have since found a *Nautilus*, apparently the *N. hexagonus* of the Kelloways rock; but being crushed, I dare not be positive.

A little higher are occasionally found remains of at least two species of *Astacus* ? generally very imperfect.

In the middle portion of the stratum I have met with no fossils, but nearer its junction with the calcareous grit are occasionally obtained small specimens of *Pinna lanceolata*. None of the above species are abundant, but the most frequently found is the *Belemnites gracilis*; indeed the Oxford clay of Yorkshire will not bear any comparison with that of Huntingdonshire and other midland counties, either in the number or beauty of its organic remains.

The following fossils I have not seen from any other stratum:

Nucula nuda.	Ammonites Vernoni.
——— elliptica.	——— cristatus.
Pinna mitis.	——— oculatus.
Belemnites gracilis.	

Pinna lanceolata, *Gryphæa bullata* and *Astarte carinata* appear to connect the clay with the calcareous grit above, whilst *Ammonites athleta* and *Belemnites abbreviatus* seem to unite it with the Kelloways rock below.

It is difficult to conceive what can have caused the sudden want of the peroxide of iron, after the deposition of the Kelloways rock. Whilst the upper portion of the latter is charged with so large a proportion, the blue clay above contains none, the line of demarcation being as distinct as in any drawn section : the iron reappears towards the upper portion of the clay, and gradually blends it with the calcareous grit.

The Oxford clay is of no utility in domestic œconomy. It serves, however, as an impermeable basis, resting upon which the calcareous rocks, forming our tabular hills, are converted into vast natural reservoirs. On the sides of these hills the clay is rarely visible, but the numerous springs which issue forth form an useful guide in separating it from the calcareous grit.

In a future memoir, I purpose to illustrate the distribution of organic remains in the remaining strata of the Yorkshire coast.

General Stratigraphical Table of the Formations described in the preceding pages, but in descending order.

Oxford Clay.

Upper beds arenaceous, tinged with peroxide of iron; they gradually become more argillaceous, and of a blue colour towards the bottom	130 feet.
Lower beds argillaceous, blue, splitting into thin laminæ and fragments	

Kelloways Rock.

Hard rock, much ironshot.....	5 feet.
Soft and variable sandstones; at Scarborough of a green colour, at Hackness softer and yellow	35 —
	40

Cornbrash.

Fissile oolite, easily decomposed by the atmosphere	6 inches.
Softer rock, sometimes ironshot	2 feet.
Hard ironshot rock	2 —
Blue clay, 3 inches to	4 —
	8

Upper Sandstone and Shale.

A variable series of sandstones and clays.....

Systematic List of Fossils enumerated in the Memoir.

GENUS AND SPECIES.	REFERENCE.	STRATUM.
Plantæ.		
Equisetum	.....	Upper sandstone and shale.
Cyclopteris digitata	Lindley and Hutton, Pl. 64*	———
Otopteris obtusa.....	Lindley and Hutton, Pl. 128	———
Pecopteris Murrayana	Adolphe Brongniart, Pl. 126, f. 1—5†.	———
Carpolithes	.....	———
Dicotyledonous? wood	.....	Kelloways rock.
Echinidæ.		
Cidaris vagans	Phillips, t. 7, fig. 1‡.....	Cornbrash.
Cidaris	.....	———
Clypeus orbicularis.....	Phillips, t. 7, fig. 3	———
——— clunicularis	Phillips, t. 7, fig. 2	———
Galerites depressus.....	Phillips, t. 7, fig. 4	———

* Fossil Flora of Great Britain, 1831–1837. † Hist. des Vég. Fossiles, Tome 1, 1828–1836.
‡ Geology of Yorkshire, Part I. 1829.

GENUS AND SPECIES.	REFERENCE.	STRATUM.
Crustacea.		
Astacus rostratus	Phillips, t. 4, fig. 20	Kelloways rock.
Astacus?		Oxford clay. Cornbrash.
Annulata.		
Serpula intestinalis	Phillips, t. 5, fig. 21	Oxford clay. Cornbrash.
Conchifera.		
Pholadomya Murchisoni	Min. Con., t. 545*	Cornbrash.
——— ovalis	Min. Con., t. 226	———
Mya literata	Min. Con., t. 224	———
——— calceiformis	Phillips, p. 169	———
Amphidesma recurvum	Phillips, t. 5, fig. 25	Kelloways rock.
——— decurtatum	Phillips, t. 7, fig. 11	Cornbrash.
——— securiforme	Phillips, t. 7, fig. 10	———
Sanguinolaria undulata	Min. Con., t. 548. Phillips, t. 5, fig. 1.	———
Lucina lirata	Phillips, t. 6, fig. 11	Kelloways rock.
Astarte carinata	Phillips, t. 5, fig. 3	Oxford clay.
——— lurida	Min. Con., t. 137	———
Cardium citrinoïdeum	Phillips, t. 7, fig. 7	Cornbrash.
——— dissimile?	Min. Con., t. 553. Phillips, t. 5, fig. 27.	———
Isocardia minima	Min. Con., t. 295. Phillips, t. 7, fig. 6.	———
Cucullea, sp. n.		———
Nucula nuda	Phillips, t. 5, fig. 5	Oxford clay.
——— elliptica	Phillips, t. 5, fig. 6	———
Trigonia costata	Min. Con., t. 85	Cornbrash.
——— clavellata	Min. Con., t. 87	———
Unio peregrinus	Phillips, t. 7, fig. 12	———
Modiola cuneata	Min. Con., t. 211. Phill., t. 5, fig. 28, var.	———
Pinna mitis	Phillips, t. 5, fig. 7	Oxford clay.
——— cuneata	Phillips, t. 9, fig. 17	Cornbrash.
——— lanceolata	Min. Con., t. 281. Phillips, t. 4, fig. 33.	Oxford clay.
Avicula Braamburiensis	Phillips, t. 6, fig. 6	Kelloways rock.
——— expansa	Phillips, t. 3, fig. 35	Oxford clay. Kelloways rock.
Lima rudis	Min. Con., t. 214	Cornbrash.
Plagiostoma interstinctum	Phillips, t. 7, fig. 13	———
——— rigidulum	Phillips, t. 7, fig. 14	———
Pecten lens	Min. Con., t. 205	———. Kelloways rock.
——— fibrosus	Min. Con., t. 136. Phillips, t. 6, fig. 3.	Kelloways rock.
——— inæquicostatus	Phillips, t. 4, fig. 10	Cornbrash.
——— demissus	Phillips, t. 6, fig. 5	———
Gryphæa dilatata	Min. Con., t. 149. Phill., var. β. t. 6, fig. 1.	Kelloways rock.
——— bullata	Min. Con., t. 368. Phillips, t. 4, fig. 36.	Oxford clay.
Ostrea Marshii	Min. Con., t. 48	Kelloways rock. Cornbrash.
——— undosa	Phillips, t. 6, fig. 4	———

* Mineral Conchology of Great Britain, by J. Sowerby and J. de C. Sowerby, Vols. I. to VI., 1812–1829.

GENUS AND SPECIES.	REFERENCE.	STRATUM.
Terebratula ornithocephala ..	Min. Con., t. 101	Kelloways rock. Cornbrash.
——— digona	Min. Con., t. 96	Kelloways rock.
——— socialis	Phillips, t. 6, fig. 8	———
Mollusca.		
Melania vittata	Phillips, t. 7, fig. 15	Cornbrash.
Cirrus depressus	Phillips, t. 6, fig. 12	Kelloways rock.
Trochus guttatus	Phillips, t. 6, fig. 14	———
——— granulatus	Min. Con., t. 220	Cornbrash.
Turbo sulcostomus	Phillips, t. 6, fig. 10	Kelloways rock.
Rostellaria bispinosa	Phillips, t. 6, fig. 13	———
——— a new species, (p.147.)	.....	———
——— trifida	Bean. Phillips, t. 5, fig. 14	Oxford clay.
Terebra granulata	Phillips, t. 7, fig. 16	Cornbrash.
Belemnites tornatilis	Smith*, Clunch clay, fig. 1	Kelloways rock.
——— abbreviatus	Miller, Geol. Trans., 2nd Ser., II. 7, 9. Min. Con., t. 596.	Oxford clay. Kelloways rock.
——— gracilis	Phillips, pl. 5, fig. 15	———
Nautilus hexagonus	Min. Con., t. 529	Kelloways rock. Oxford clay?
Ammonites Herveyi	Min. Con., t. 195	Cornbrash.
——— terebratus	Phillips, p. 174	———
——— Gowerianus	Min. Con., t. 549. Phill., t. 6, fig. 21, var.	Kelloways rock.
——— sublævis	Min. Con., t. 54. Phillips, t. 6, fig. 22.	———
——— Calloviensis	Min. Con., t. 104. Smith, Kel. rock, f. 3.	———
——— ———, var. Gulielmi.	Min. Con., t. 311	———
——— Kœnigi	Min. Con., t. 263. Phillips, t. 6, fig. 24.	———
——— gemmatus	Phillips, t. 6, fig. 17	———
——— bifrons	Phillips, t. 6, fig. 18	———
——— flexicostatus	Phillips, t. 6, fig. 20	———
——— athleta	Phillips, t. 6, fig. 19	Kelloways rock & Oxford clay.
——— Sutherlandeæ	Min. Con., t. 563	———
——— perarmatus	Min. Con., t. 352	———
——— Duncani	Min. Con., t. 157. Phillips, t. 6, fig. 16.	———
——— plicatilis	Min. Con., t. 166	———
——— four new sp. (p.147.)	.....	———
——— oculatus	Phillips, t. 5, fig. 16	Oxford clay.
——— Vernoni	Phillips, t. 5, fig. 19	———
——— cristatus	Min. Con., t. 421	———
Pisces.		
Orodus *or* Psammodus	Agassiz	Kelloways rock.
Teeth of Squalus	Phillips, t. 5, fig. 22	Oxford clay.
Reptilia.		
Ichthyosaurus	.....	Kelloways rock.
Plesiosaurus	.....	———

* Smith's 'Strata Identified,' 1816.

X.—*On the relative Ages of the Tertiary and Post-tertiary Deposits of the Basin of the Clyde.*

By JAMES SMITH, Esq., of Jordanhill, F.G.S.

[Read November 6th, 1839.]

IN a former paper* I described the indications which I had observed of changes in the level of the sea in the basin of the Clyde, which must have taken place at times, geologically speaking, extremely recent, as the indications are met with above the *Till* or erratic block deposit; and in a subsequent paper† I stated, that from the Arctic character of several shells which have not been found recent in the British Isles, that there was strong probable evidence that the climate was colder at the period of their deposition than it is at present.

Having given a detailed account of my observations, with catalogues of the recent and fossil shells of that district to the Wernerian Society (Wern. Mem. vol. viii.), I confine myself, at present, to the results of observations made subsequently, which afford the most satisfactory evidence that in these comparatively modern deposits, there are two distinct formations differing in climate and fauna, and separated by a wide interval of time.

If a difference in the testaceous fauna characterises the tertiary period, the oldest of these, which contains about fifteen per cent. of extinct or unknown species, must be held as a tertiary formation, and belongs to the newer Pliocene or Pleistocene of Lyell, and the newest, a post-tertiary one, as all the shells hitherto discovered, agree with those of our present seas. Both of these deposits are anterior to the recent or historical period.

We have therefore, in the superficial or earthy covering of the older rocks, three distinct epochs, the newer Pliocene, Post-tertiary, and Recent. To the first of these belong the till or diluvium and the stratified marine beds of sand, gravel, and clay which lie over it, the shells of which contain a decided admixture of unknown

* See Proceedings of the Geological Society, Nov. 16, 1836, vol. ii. p. 427.

† Ibid., April 24, 1839, vol. iii. p. 118.

species. The same order of superposition is observable in the basins of the Forth and the Tay, and although scarcely anything has been done in the investigation of the marine remains imbedded in their elevated deposits, I have little doubt that, from their exact agreement, both in position and in mineral structure, they will be found to be of the same age as those of the Clyde*. Should they prove to be identical, the submarine forest of the Tay must also belong to the tertiary period, being overlaid by the stratified marine beds.

These deposits pass from below the present level of the sea to an elevation which has not been ascertained. In Scotland organic remains belonging to them have been found at the height of 350 feet; and if the elevated terraces of Glenroy are of marine origin, they probably belong to the same period, and indicate a change of upwards of 1000 feet. I am convinced that a very great proportion of the superficial beds of sand, gravel and clay, as well as the unstratified till or diluvium, are tertiary; although where organic remains are wanting, there must always be some uncertainty. During the succeeding or post-tertiary period, a movement of elevation of about 40 feet must have taken place. At this height (40 feet) the sea appears to have been stationary for a length of time greatly exceeding the present period of repose. This is indicated by a magnificent range of inland sea cliffs, with beds of gravel and sand interposed between them and the sea. All the testacea hitherto discovered in these beds agree with existing species in the British seas; the number of shells collected from them amounts to about 160. I was at first led to suppose that they contained a small proportion of unknown species, latterly there was only one to which I could not assign a living analogue, viz. *Arca papillosa*, but on that point there is now no doubt; for, within these few weeks, Captain Portlock sent me a specimen which he had discovered recent on the coast of Ireland. The raised beaches of the period immediately preceding the last changes of level in the basin of the Clyde, do not therefore contain any mixture of unknown shells, although probably accumulated long anterior to the recent period.

During the existing geological epoch, no change of level appears to have taken place in this locality, whilst there is direct evidence that, at least as far back as the time of the Romans, it was precisely the same as at present†.

I subjoin a list of the marine shells which have been found in these beds, and which are not known as inhabitants of the British seas. In stating the proportion which they bear to the recent British species, I have made allowance for the probability of some of them being still inhabitants of our seas, although, as yet,

* This is partly confirmed by the *Nucula pygmæa*, one of the unknown shells of the Clyde beds, having been found in the elevated beds of the Tay by Mr. Lyell.

† See Proceedings, vol. ii. p. 427.

undiscovered; and for others being varieties of those which are. Had I included them all, the proportion would be nearly 20 per cent. Upon separating the fossil catalogue, in my paper in the Memoirs of the Wernerian Society, vol. viii., into what I consider tertiary and post-tertiary species, I find the number of the former 151, of which 27 species are unknown as British.

The researches of the Rev. David Landsborough, in the summer of 1840, fully confirm the existence of two separate epochs in the elevated marine beds, which are newer than the till or diluvium. At Stevenston in Ayrshire he found, at the depth of thirty-five feet under the surface, a bed of blue clay, with newer Pliocene shells: out of twenty-seven species, there were eight of them extinct or unknown. In a superficial raised beach, in the same parish, he found forty-seven species, all recent; and in another at Largs, in the same county, sixty-eight species occur.

It is remarkable that none of the fossils of the older of these beds have been yet found mixed up with those of the newer or raised beaches. (May 1841.)

1. *Tellina proxima*, Wern. Mem., vol. viii. p. 105, Pl. I. f. 21.—Closely allied to the *T. prætenuis*, a crag fossil. It has been discovered in a recent state in the Arctic seas, beyond Behring's Strait, by Capt. Beechy, and fossil at Udevalla.
2. *Crassina multicostata*, Wern. Mem., vol. viii. p. 104, Pl. I. f. 20; Phil. Trans. 1835, Pl. II. f. 21.—It resembles the *C. compressa*, a recent species, but is less regularly striated. M. Deshayes says that it is recent in Norway and Sweden; Mr. Lyell found it in a fossil state at Udevalla; and Mr. Murchison, in Russia. (1840.)
3. *Crassina propinqua*, nearly related to the last, but with a much thicker hinge (1841).
4. *Crassina Withami*, Wern. Mem., vol. viii. p. 105, Pl. I. f. 25.—Found by Mr. Witham in a fossil state at Bridlington, and by Mr. Forbes at Wick; a single valve was dredged by Mr. Sowerby and me in Rothsay Bay: it is perhaps, therefore, a recent shell, but as the newer *Pliocene* deposit passes below the sea at Bute, this is not a conclusive proof that it is so.
5. *Crassina borealis*, Chemnitz, vol. vii. p. 26, Pl. XXXIX. f. 412.—Recent in the North Sea, fossil in the upper crag.
6. *Mya* ————. Closely allied to *M. truncata*, but differing so constantly in the muscular impression that Mr. G. Sowerby considers it a separate species. Found fossil by Mr. Lyell at Udevalla.
7. *Pecten Islandicus*, Brown's Illust., Pl. XXXIII. f. 3.—Although this shell appears in the works of Turton, Fleming, and Brown, as a recent British species, I am satisfied, from the localities given, that the specimens described were from the ancient beds in which it is very abundant, and that it has not hitherto been found in a living state in our seas; it occurs recent in the North Sea and at Newfoundland, and fossil at Udevalla.
8. *Nucula oblonga*.—This shell also appears in Brown's Illustrations, Pl. XXV. f. 17, but as it is from a locality whence these fossils are abundant, and as it has not been found since in a recent state, it is probably one of them; it resembles the *N. minuta*, but is larger and not transversely striated. Mr. Gray considers it an Arctic shell. Found fossil by Mr. E. Forbes in the Isle of Man, by Capt. Portlock in Ireland, at an elevation of 400 feet, and by Mr. Murchison in Russia.
9. *Nucula antiqua*.—This shell is transversely striated, and is higher in proportion to its breadth than the *N. oblonga*.
10. *Nucula pygmæa*, Goldfuss, Pl. CXXV. f. 17; Wern. Mem., vol. viii. p. 107, Pl. II. f. 10; Philippi Mollusc. Sicil., Pl. V. f. 9. In the catalogue in the Wernerian Memoirs it is named *N. gibbosa*, but is undoubtedly the *N. pygmæa* of Goldfuss, a fossil from Mechlenburg. Mr. Lyell found it in an elevated deposit at Dundee; Mr. S. Wood in the crag, see his Catalogue, Nat. Hist. Mag., 1840, p. 298. It agrees also with the Sicilian fossil figured and described by Philippi.
11. *Cytherea lævigata*.—A small but very distinct species (1841).

12. *Mactra striata*, Wern. Mem. vol. viii. p. 106, Pl. I. f. 22.
13. *Saxicava sulcata*, Wern. Mem., vol. viii. p. 97, Note ; Phil. Trans., 1835, Pl. II. fig. 25.—Closely allied to the *S. rugosa*, but much larger and more regular in the transverse striæ or ridges. It occurs in a fossil state at Udevalla.
14. *Panopæa Bivonæ*, Wern. Mem., vol. viii. p. 107, Pl. II. f. 4 ; Philippi Mollusc. Sicil., Pl. II. f. 1.—Fossil in the crag and Sicily ; a single specimen has been dredged on the east coast of England, now in the possession of Mr. Jeffries (vide Nat. Hist. Mag., v. viii. p. 582), which Mr. Sowerby considers to be the same species.
15. *Natica clausa*, Wern. Mem., v. viii. p. 103, Pl. I. f. 16 ; Phil. Trans., 1835, Pl. II. f. 7.—Recent in the Arctic seas and fossil at Udevalla.
16. *Natica glaucinoides*, Min. Con., p. 479, f. 5.—Found also in the crag.
17. *Natica fragilis.*—This shell is smaller and more fragile than the *N. glaucinoides*, and has no callus or tooth over the umbilicus.
18. *Nassa Monensis.*—Found by Mr. E. Forbes in an elevated deposit in the Isle of Man. It differs from the *N. macula* in having the spire less produced ; the body-whorl much more ventricose and the longitudinal ribs fewer. It appears intermediate between the *N. macula* and *N. ambigua.*
19. *Buccinum granulatum*, Min. Con., Pl. CX. f. 4.—Found in the brick earth of the Nar, which I consider a newer pliocene deposit (Woodward's Geol. of Norfolk, p. 36). It is also a crag fossil.
20. *Buccinum striatum*, Wern. Mem., v. viii. p. 100, Pl. I. f. 9.
21. *Trochus inflatus*, Wern. Mem., v. viii. p. 1. f. 10.—This appears to be the same as one found fossil at Udevalla, figured by Hisinger, *Lethæa Suecica*, Pl. XXX. f. 3, and erroneously supposed to be the *T. tumidus* of Montagu. Recent in the Arctic seas, in Mr. Bunbury's collection.
22. *Turbo expansus*, Wern. Mem., v. viii. p. 101, Pl. I. f. 12.—"Common in the Arctic seas."—Deshayes.
23. *Velutina undata*, Wern. Mem., v. viii. p. 101, Pl. I. f. 15.—This shell is also said by M. Deshayes to be an Arctic species.
24. *Fusus Peruvianus*, *Murex*, Sow. Min. Con., Pl. CCCCXXXIV. f. 1. ; Wern. Mem., v. viii. p. 100, Pl. II. f. 5 and 9, *Lethæa Suecica*, Pl. XXX. f. 7.—It is also found fossil in the crag and at Udevalla, and recent in the Arctic seas.
25. *Fusus imbricatus*, Wern. Mem., p. 100, pl. I, f. 5, 6, and II. f. 7.—In my catalogue in the Wernerian Memoirs this is considered as the young of *F. Peruvianus*, but as no such change takes place in its analogues from the crag and Arctic seas, I am now satisfied it is a distinct species.
26. *Fusus curtus.*
27. *Bulbus Smithii*, Wern, Mem., v. viii. p. 103, Pl. I, f. 18.—Resembles a *Natica*, but is destitute of an umbilicus or cavity on the pillar lip ; there is an unnamed shell from the Sicilian Pleistocene in the Collection of the Geological Society, which I consider to be identical with it.

As this catalogue differs considerably from that published in the Wernerian Memoirs, I think it right to explain that the new shells have been discovered since it was printed, and that I omit the following for the reasons assigned.

1. *Rissoa Fallax*, Wern. Mem., Pl. I. f. 7, 8.—Considered by Mr. Sowerby to be *Cingula cingilla*, H.
2. *Arca papillosa*, Ib., Pl. I. f. 19. Since discovered recent by Capt. Portlock.
3. *Turritella cingulata*, Ib., Pl. I. f. 23. Want of evidence. See Memoir, p. 101.
4. *Bulla Ampulla.*
5. *Oliva.* These two last were found in the elevated marine beds, described by Mr. Murchison in his Silurian System ; but till the testaceous fauna be more thoroughly investigated, it is impossible to say whether they belong to the same period as the Clyde shells or not.

XI.—*A Letter to Charles Lyell, Esq., on some Changes of Level which have taken place in Denmark during the present period.*

By GEORGE FORCHHAMMER, Phil. Doct., For. Mem. G.S.

[Read May 31, 1837.]

My Dear Sir,

THE great interest which you have taken in the geology of Denmark, and the influence which you have exerted on the whole progress of geology, more especially of that portion which relates to our knowledge of the newer formations, make me wish to communicate, through you, some facts which appear to me worthy of being known to a Society, which has so much promoted our science.

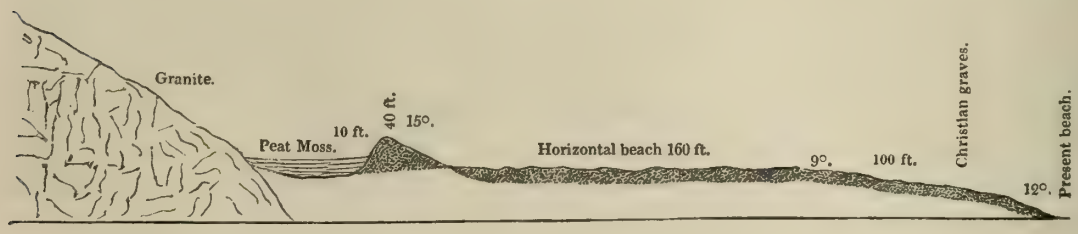
You are satisfied that a great part of Sweden is rising, not uniformly, but in a manner which generally decreases in amount from north to south on the Swedish coast of the Bothnian Gulf*; and in your last anniversary speech you have published some observations by Mr. Nilsson on the subsidence of Scania, the southernmost part of Sweden†. Thus it appears to be proved, not only that the elevation varies in different places, but that even a movement in an opposite direction takes place in some parts of this extensive country. In corroboration of these facts, I will only mention, that the island of Saltholm, situated in the Sound, and opposite to Copenhagen, is mentioned in the records of the Chapter of Roeskilde in the 13th century, on account of the income which the clergy derived from it. At present the island is hardly five feet above the level of the Sound, and it is almost every autumn overflowed by the sea, some artificial mounds serving as places of safety for the cattle which in summer graze on the island. Now it is evident, that if Saltholm has risen during the last 600 years, the movement must have been at a much slower rate than even in the island of Bornholm, which rises about one foot in a century; and considering how small a portion of Saltholm would be left if it now subsided only two feet, the island would hardly have been worth the notice of the rich Chapter of Roeskilde; we may therefore fairly infer that Saltholm either has been stationary or may have subsided during the last 600 years.

* Phil. Trans. 1835.

† Proceedings Geol. Soc., vol. ii. p. 506.

On the Danish coast of the Sound, six miles to the north of Copenhagen, a most decided beach occurs about six feet above the level of the present Sound, and so completely out of the reach of the sea, that a range of houses has been built between the ancient beach and the present shore. This renders it highly probable that the level on the Danish coast changes in a proportion different from that which takes place on the Swedish shore; and this difference seems to be connected with the fact, that the slight earthquakes which are felt in Sweden almost every year are never experienced in Denmark, and that a shock of an earthquake which in August 1829 was felt so strongly on the Danish coast of the Sound, that the terrified fishermen in some places left their houses, was not at all perceived on the opposite Swedish shores.

I will, however, not dwell on these points, but proceed to detail my observations on the island of Bornholm, the rocky base of which makes a change of level more easily to be observed. The greater part of Bornholm consists of a granitic rock, which forms the whole eastern shore of the island, and rising abruptly out of the water, the sea is so deep that it generally allows large vessels to lie close to the shore. To the height of 250 feet, the granite is covered by a stiff, loamy soil; but above that level nothing is found except barren gravel, the result of the disintegration of the granite. The yellow loam everywhere contains fragments of slates and transition limestones, the latter possessing the character by which they are easily proved to have been transported from the island of Gothland. None of the plutonic rocks, so common in our boulder formation, are to be found here; and by their absence and the frequent occurrence of the clay slates, which are extremely rare in the boulder formation, this bed is proved to be of a different origin. It is not a sea-beach, all the stones being completely mixed with the clay, and on the west side of the granitic ridge no trace of it can be found. These observations lead me to conclude that the bed of loam is the result of a violent inundation breaking in from the north-eastern parts of the Baltic, the effect of which may be seen everywhere, both in the form of the Danish shores and the immense deposits of sand which cover a great part of Denmark, and which evidently have been swept away from more easterly beds of the boulder formation.



Nearer to the present shore (see accompanying woodcut), at a height of about forty feet, the first beach may be observed on Bornholm. Wherever the granitic mountains recede a little from the coast and form a small bay, the granite pebbles of the beach appear to have choked it up, and to have separated a small pond from the sea, which in the course of ages has been filled with peat. This ridge has only a small breadth and slopes towards the shore at an angle of 15°, forming a wall of about ten feet high, and abutting on a plain entirely formed of beach-stones. This plain is completely horizontal and has a breadth of about 160 feet. It is surrounded by another plain of about 100 feet broad, inclining toward the sea at an angle of 9° or 10°, to which succeeds the present beach, sloping at an angle of 12° or 13°; the pebbles are of uniform size throughout the beach, and consist of the same granite as the solid rock. My explanation of these facts is the following: after the inundation before mentioned, and which I conceive entirely changed the face of Bornholm and the rest of Denmark, a beach was produced at the shore, but I infer that its accumulation was interrupted by an earthquake, which suddenly threw up the island about ten feet; and that a very long period of perfect quiet followed, during which no elevation took place, but the horizontal beach was formed. Subsequently I am of opinion a continuous but very slow rising began, which formed the sloping beach; and, according to observations of the inhabitants and my own, this rising is still in progress. On this sloping beach are graves marked merely by a ring of stones, a little larger than the general size of the beach-stones, and very different in structure from the graves which our heathen ancestors erected. Now, according to a communication from Mr. Finn Magnussen, it was a custom in the northern countries to bury the early Christians on the beach where the sea and land separated, and when afterwards the Christians got the power, the same kind of sepulchre was used for the heathens. This happened about the year 900, and we may consequently come to something like a rough calculation as to the time when this beach was formed. The elevation of the island, as shown by the sloping beach, would thus have been about one foot in a century, and the beginning of the regular elevation of the island would have been about 1600 years ago. The slope being completely regular, it is most probable that the rise of the island and the lateral addition to the beach were quite uniform during the whole period; and by supposing this lateral extension to have been equally uniform during the formation of the horizontal beach, we require 2500 years for the gradual accumulation of the horizontal beach, which carries back the era of the great earthquake to about 4000 years before our time. I do not pretend to say that this chronological calculation can be by any means exact, yet I think it may be of some use; and future observers on Bornholm, availing them-

selves of the facts which I have tried to point out, may certainly bring the calculation much nearer to the truth.

The features of the beach now described, occur, with some small differences, everywhere on the granitic, eastern shore of the island; but wherever the coast is formed of sandstones and slates of the transition-class, or of the beds of sandstone, sand, clay, and limestone, belonging to the lias, the oolitic series, and the green-sand formation, no regularity in the beaches can be traced, nor can any one be seen more than twenty feet above the present level of the sea; and it seems as if these formations have suffered a less regular elevation than the granite.

Over the whole of Denmark, Sleswick, and Holstein, shells of species living at the present time in the German Ocean may be found, sometimes at considerable heights above the level of the sea. Thus not far from Bornhövd in Holstein, certainly exceeding 150 feet above the Baltic, occurs a bed of pebbles associated with *Cardium edule*, *Littorina littorea*, *Buccinum undatum*, and *Ostrea edulis*. The specimens of the last shell are much smaller than the *O. edulis* now living on our coast, but they agree with those found fossil in the raised beds of recent marine shells of England. Thus the elevation of the country in modern times is certainly proved, but this elevation must be much older than the inundation from the east before mentioned. After that catastrophe subsidences occurred, of which I will mention one with rather interesting features; between the island of Römöe and the shores of the dukedom of Sleswig, is a submarine forest nine feet below the present high water, the roots still branching out into the sand. According to the evidence of all the fishermen, this forest consists of fir, a tree which likewise occurs in almost all our peat-mosses, being the oldest vegetation. At other places far beyond the present shore, forests of oak are found in the same situation below the mean height of the sea.

Before I conclude this letter, I wish to record the following phænomena. On the islands on the western shore of Sleswig traces of an inundation may be found to the great height of about sixty feet above the present high-water mark, which happened while the islands have been inhabited by man, because we find tumuli partly destroyed by the inundation. The effect and height of this flood may easily be traced by a bed of pebbles, partly rounded, partly angular, containing now and then fragments of bricks, and easily distinguished from a beach by its occurrence in one single bed hardly a foot thick, undulating with the surface, and in one place found only a few feet above high-water mark, while at others it is about fifty feet above it. I consider it as the result of the washing away of the finer materials, or the sand and sandy clay.

London, March 20th, 1837. G. Forchhammer.

XII.—*Description of Bones of the Mammoth found in the deep sea of the British Channel and German Ocean.*

By Capt. J. B. MARTIN, Harbour-Master at Ramsgate.
Communicated by Sir JOHN RENNIE, F.G.S.

[Read June 5th, 1839.]

FRAGMENTS of fossil remains have been often brought to Ramsgate by the men employed in trawling for ground fish in the North Sea and the Straits of Dover. Charged with worms and covered with fetid marine substances, they have been seldom capable of preservation; but sometimes perfect specimens have been procured, and I have generally succeeded in purchasing them. The fishermen are also occasionally impeded by masses of granite, serpentine, sandstone, slate, and various other stones which are scattered indiscriminately over the bed of the ocean. Some of these blocks are much worn and rounded; and in no instance do they present that regularity of shape which might lead to the inference of their having formed part of shipwrecked cargoes. The fishermen bring the masses to land for the purpose of clearing their ground. In many localities, the rugged state of the bottom will not allow them to trawl.

In 1827 an enormous tusk was landed at Ramsgate, and purchased by Mr. Foster. Its length was nine feet and its greatest diameter eight inches; but the alveolar extremity was wanting, and the dimensions of the tusk must consequently have been much greater. The outer crust consisted of very thin laminæ, and the interior portion of a soft substance resembling putty. Being left exposed to the action of the atmosphere it soon mouldered away. I am not aware in what part of the British Channel it was found.

The next specimen which excited my attention was discovered in the red clay on which the town of Ramsgate stands. It is a fine molar, in the possession of Mr. Fairholme, and was obtained in digging the foundations of a house in King-street. The red clay rests upon chalk, and in different parts of the town varies in thickness from ten to twenty-three feet.

In 1835 a very large, flat, decayed fragment of bone perforated by worms, and a

soft, decayed tusk, eleven feet in length, were dredged up between Boulogne and Dungeness. The bottom of the channel at the point where it was found, consists of blue clay with rounded pebbles. The fishermen cut the tusk to pieces to obtain some ivory fit to manufacture. A section which I procured from near the alveolar cavity, is of an oval shape and measures nineteen inches in circumference.

In 1837, while trawling between the two shoals, called the Varn and Ridge, covered at low tide with twenty fathoms water, a fisherman suddenly encountered a heavy mass, which proved to consist of enormous bones; the net broke, but a humerus, which I purchased, was secured. The upper articulation is wanting, and that part appears to have been most decayed. It is of a very stony texture, and its interior is filled with marine substances. The following are the dimensions:—

Length from the lower condyle to the fracture	38 inches.
Presumed original length	45 —
Circumference at the upper part of the shaft	31 —
Ditto, in the centre	20 —
Ditto, around the lower part, just above the condyle	31 —
Width across the condyles	10 —

The Varn and Ridge lie in the mid-sea between Dover and Calais, and form a line of submarine chalk ridges, extending parallel to the cliffs on each side of the Channel, and trending toward the North Sea. The Overfalls and Galloper sands are continuations of the same line. The flanks of all these submarine ridges are steep, and there are deep gullies in the intermediate spaces, filled with patches of boulders and blocks of various stones and muddy ground. Some of these masses are large spherical septaria, traversed internally by veins of iron pyrites, and consist externally of a ferruginous crust of uniform thickness. Thus these interesting animal remains appear to repose in marine valleys in a similar manner to the analogous bones on land; and it is evident that they are thickly strewed over the bed of the sea in these latitudes. They are never found on the summits of the banks or shoals, but invariably in deep water in the hollows.

At the back of the Goodwin-sands an elephant's tusk was dredged up. The part containing the alveolar cavity was broken off, but its length was 78 inches and its circumference 12 inches. Its curvature was equal to a semicircle, turning outwards in its line of projection. The tusk was sent to a cutler at Canterbury, by whom it was sawn into five sections; but the interior was found to be fossilized and unfit for use. It is now in my possession. From the same locality, I have also a piece of fossilized tree, the heart of which is changed into a beautiful jet.

In the early part of 1839 I succeeded in adding to my collection a perfect femur of a Mammoth. It was trawled up in the North Sea, in 20 to 25 fathoms low

water, about mid-way between Yarmouth and the coast of Holland, 65 miles E.N.E. of the Galloper-sand, and about 120 miles from the locality where the humerus was obtained. Its dimensions are as follows:—

Length from the head of the femur to the lower condyle	49 inches.
Circumference of the head of the femur	24 —
Width across the ball and the great trochanter	18 —
Circumference of the neck of the femur	42 —
——— of the centre of the shaft	18 —
——— of the lower part of the shaft above the condyle	29 —

The lower condyle is partially worn away.

I have also two molars of different sizes which were trawled up at considerable distances from each other in the British Channel and at different periods. My collection therefore contains portions of six Mammoths; and Mr. Fairholme's molar found in Ramsgate constitutes part of a seventh.

Extract from a Notice, by Dr. Buckland, on Teeth of the Elephant obtained from the Bristol and British Channels, read June 5th, 1839.

Sir John Trevelyan possesses a very large molar of an Elephant, found three or four years ago in the bed of the Bristol Channel near Watchett; and an Elephant's molar tooth, in the collection of Lady Ilchester, was thrown up on the Chesil-bank, Dorsetshire.

XIII.—*On Subsidences produced by working Beds of Coal. In a Letter to C. Lyell, Esq., F.G.S., from* John Buddle, Esq., F.G.S.

[Read November 6th, 1839.]

SUBSIDENCE of the surface invariably follows the working of the subjacent coal, when sufficient pillars are not left to support the overlying mass. The extent of such subsidence is governed by the following circumstances:

1st. The depth of the seams of coal below the surface.

2nd. The thickness of the seam or seams.

3rd. The nature of the strata between the surface and the seams of coal.

4th. Whether the pillars of coal are wholly or partially worked.

If the depth from the surface does not exceed twenty-five or thirty fathoms, and sandstones form the predominant strata, then the subsidence is nearly, if not fully, equal to the thickness of the seam of coal which has been taken out; but should *metal-stone* or shale form the predominant strata, the subsidence is less. This rule I consider to hold good in all cases, let the depth from the surface be what it may; that is to say, the subsidence is always greater under a sandstone than under a metal-stone cover*.

Whenever a lower seam is worked after an upper one has been removed, and the surface lowered in the manner above stated, a *second set*, or lowering, takes place. I have known this to occur three successive times, as will afterwards be shown; and that it might not, under certain conditions of the stratification, take place an indefinite number of times, I am not prepared to say.

The thickness of the coal removed affects the degree of subsidence; but I am not enabled to state in what proportion it operates, not having had an opportunity of making correct observations on this point.

The degree of subsidence, however, does not depend so much on the thickness of the coal as on the effectual removal of it, technically called "Clean Working." If a considerable portion of the coal should be left, although by no means adequate to the support of the superincumbent strata, it yet retards the subsidence and prevents the downward pressure of the mass from exerting that degree of force and momen-

* Cover means the whole thickness of the strata between the seam and the surface.

tum which it would otherwise do; besides, the small portions of coal which have been left occupy a certain part of the excavation when crushed down.

These observations apply more particularly to the Newcastle system of working, or "short work," where rectangular pillars are left, in the first instance, and afterwards removed.

In the working of those pillars, *stooks*, or blocks of coal of considerable strength, are frequently left as props to protect the colliers from the exfoliations of the roof. In this case, a subsidence of the strata above invariably takes place; but its extent in the *first instance* is governed by the degree of resistance which those stooks of coal present to the downward pressure of the mass. When the sinking of the strata is retarded or stopped in this manner, before the excavation whence the coal has been extracted is entirely filled, the place is said to be "half or three quarters, etc. crept." A large tract of a coal-mine not unfrequently remains for several years in this state, without almost any perceptible change taking place; yet in course of time, from the exfoliation of the coal in those "stooks," and the operation of the atmosphere, a further subsidence, called a *second creep*, takes place, and generally continues until the excavation is completely closed.

In the Yorkshire system of "long work," where the coal is all taken out in the first instance, except small temporary pillars, in addition to which wooden props, together with a sort of stone pillaring called "gobbing," are placed for the protection of the colliers, the subsidence of the strata immediately follows the removal of the coal, and the excavation is completely filled, so that no second settlement or *set* takes place.

I have already observed, that the extent of settlement, as shown on the surface, from working coal, depends upon so many contingencies, that it cannot be subjected to any calculation. It rarely happens that the perpendicular depth of a sinking of the surface above coal-workings can be accurately ascertained, as fixed land-marks are seldom attended to in such cases. Railways, or reservoirs of water, however, occasionally afford the means of ascertaining, with tolerable accuracy, the extent to which the surface has subsided by the working out of the coal.

From the formation of a pond of water upwards of three feet deep on a level surface, from underneath which a six-feet seam of coal had been worked at the depth of 100 fathoms, about one-fourth part of the seam having been left in *stooks*, as already described, I ascertained that the subsidence of the surface at its greatest depression had been rather more than three feet. In this case the sandstone strata predominated.

The next case which I have had an opportunity of observing with tolerable accuracy is a more interesting one, as it shows three distinct periods of subsidence,

as three seams of coal were successively worked away below. The tract of ground alluded to is of a quadrangular figure, of about twenty-three acres in area, and is crossed by a railway near its eastern or narrowest end. It is in the Marquis of Londonderry's Pensher Colliery, in the county of Durham.

The tract in question contains the following five seams of coal—see Section :

	Thickness.		Depth below the Surface.
	Ft.	In.	Fathoms.
1st.—The Three-quarter Seam	1	8	$54\frac{1}{2}$
This seam is not deemed workable at present.			
2.—The Five-quarter Seam	3	6	62
3.—The High-main ditto	6	3	73
4.—The Maudlin ditto	5	0	$83\frac{1}{2}$
5.—The Hutton ditto	3	8	107

The three latter beds have been removed, and caused the subsidence of the surface about to be described, and the Five-quarter is now in course of working.

No. 3. The High-main seam was the first which was wrought in the pillars, and was finished in 1829, when a settlement in the surface was noticed. This was immediately discovered by the lowering of the railway, which required to be raised to its original level.

No. 4. The Maudlin seam was next wrought in the pillars and finished in 1831, when a second settlement of the surface took place, and the railway had again to be raised.

No. 5. was then worked in the pillars and finished in 1833, when a third settlement of the surface took place, which required the railway to be again raised to its original level.

The working of No. 2. commenced two years ago, but is not yet finished. When the pillars are all worked out, I have no doubt that another settlement of the surface will take place.

The extent of each settlement was not measured, but I have lately ascertained that the whole amount of the settlement of the surface by the three "*mine-quakes*" was five feet six inches,—the aggregate thickness of the three seams which have been worked out being fourteen feet eleven inches. This appears to be but a small degree of subsidence, considering the thickness of the coal which has been taken away. But as the railway, which is the gauge-line, passes near to one end of the excavated tract, it may not be supposed to pass over the line of the greatest depression. Indeed, on looking at the ground over the centre of the excavated tract, it appears to be much more depressed ; but as there are no land-marks by which

to ascertain the fact, I preferred taking the line of the railway, which gives the true result in that part.

The metal-stone strata also considerably exceed in thickness the beds of sandstone, and operate to make the depression less than that noticed in the former instance.

In the present working of No. 2. (the five-quarter seam) the effects of the fractures occasioned by the former excavating of the lower seams are clearly discernible. Innumerable cracks pass through the coal and pavement, as well as through the roof-stone, in a vertical direction, but they are perfectly close, except round the margin of the settlement. Here a breaking and bending of the seam, pavement and roof-stone have taken place. The cracks in the pavement are frequently open, forming considerable fissures; the coal is splintered and the roof-stone is shattered. This is not, however, the case in the interior of the settlement; on the contrary, the cracks are quite close, and the pavement is as level and smooth as if it had never been disturbed. The cracks in the coal pass through the seam without having injured, splintered, or triturated it on the sides of the cracks, as is generally the case with the natural *backs*. The only alteration produced has been to render the coal more tough and *woody*, as the colliers call it, in working than it was before these fractures took place. This effect may be attributed to the escape of the gas by the cracks; and it sometimes takes place from other causes, when the coal is said to be *winded* by the colliers.

The smoothness of the pavement in the interior of the subsided tract is due, probably, to the pressure of the superincumbent mass, which is partially, if not completely, detached from the surrounding strata, and its line of pressure is directly downwards.

I would here observe, that I never noticed any tendency to a sliding or sideway movement in any subsidence of strata occasioned by the working of coal, except the slight obliquity occasioned by the off-break at the sides of the settlement, as already described.

The facts here stated fully confirm, in my humble opinion, the hypothesis adduced in your 'Elements,' (p. 122); and when our pigmy operations can produce such palpable and analogous phænomena—what stupendous effects upon the surface of the globe may we not imagine the grand excavator of nature—the volcano—capable of producing!

Second creeps, or subsidences of the surface, sometimes occur from water being suddenly let off from old colliery-workings, after having been a long time pent up in them.

JOHN BUDDLE.

Walls End, Newcastle-upon-Tyne,
August 22nd, 1839.

XIV.—*On the London and Plastic Clay Formations of the Isle of Wight.*

By Mr. BOWERBANK, F.G.S.

[Received March 12th, 1839.]

EARLY in June 1838, in company with my friend Mr. White, I visited White Cliff and Alum Bays, for the purpose of examining the London and Plastic Clay Formations, and of determining, if possible, by a careful examination of their fossils, how far the great mass of the London clay and the beds of coloured clays and sands beneath it are entitled to be considered as separate formations*. We were induced to visit them with this view, from having some years since, in company with Mr. Morris, carefully examined the sandy beds between the London clay and the chalk at Herne Bay; and having been forcibly struck by the great similarity which the fossils procured from these sands bore to several of the species

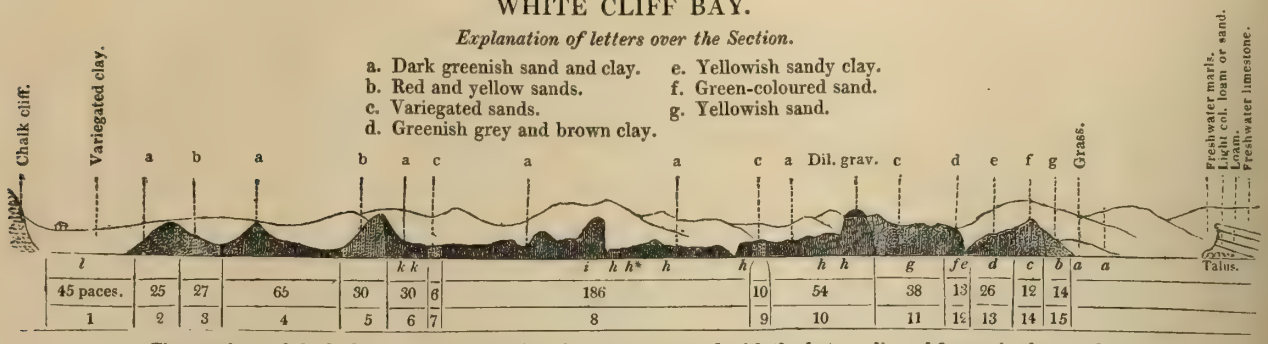
* When this paper was read before the Geological Society, I was not aware that Mr. G. B. Sowerby had examined the strata which occur between the chalk and lower freshwater formation of Mr. Webster at Alum Bay, and that he had published the result of this examination in the 'Annals of Philosophy' for Sept. 1821. In that paper he questions the propriety of Mr. Webster separating the upper or London clay from the lower or plastic clays and sands; and he says, "Everything is in favour of the opinion, that from the chalk to the lowest part of the freshwater stratum the whole is but *one formation*, consisting of various beds of sand and clay," p. 217. The merit of this idea is therefore undoubtedly due to Mr. G. B. Sowerby; neither was I aware of the existence of the paper published by Professor Sedgwick in the same work in May 1822, in which he expresses a difference in opinion on the subject, and advocates a return to the arrangement into two formations, as proposed by Mr. Webster. Professor Sedgwick prefaces his observations on Mr. Sowerby's views by stating, that "The separation of the two formations above mentioned is not marked by any extraordinary natural epoch, but is merely assumed as a convenient classification, founded on constant geological relations; on a decided difference in the composition of the constituent beds; and in a still more decided difference in their zoological phænomena." p. 339. Now the fourteen well-known characteristic London clay fossils, found by myself in the clay and sand near the chalk, marked *a* in Webster's section, decidedly negatives the assertion that that part of the formation differs in zoological phænomena from the upper portion of the London clay, marked B in the same section. Mr. Lyell also, in the 'Principles of Geology,' 1st edit., vol. iii. p. 278, states, that in the coloured sands and clays of Alum Bay there is a "distinct alternation of the two groups," that is, of the London and plastic clay beds. Why, therefore, they should be designated as separate formations, even in the latest geological publications, I cannot conceive, unless it be that it is more difficult to eradicate a confirmed error than it is to establish a new truth.—*February* 1841.

found in the London clay, we were induced to believe that the two formations which had hitherto been considered as distinct, might possibly, by a careful examination, be proved to be only the upper and lower portions of one great deposit. We commenced with a close examination of White Cliff Bay, and found the following to be the order of succession of the strata, beginning at the chalk and ending with the lower portion of the freshwater beds:—

WHITE CLIFF BAY.

Explanation of letters over the Section.

a. Dark greenish sand and clay.
b. Red and yellow sands.
c. Variegated sands.
d. Greenish grey and brown clay.
e. Yellowish sandy clay.
f. Green-coloured sand.
g. Yellowish sand.



The numbers of the beds in the following list of strata correspond with the bottom line of figures in the woodcut.

	Paces.
1. Variegated clay (principally red, corresponding with 1 and 2 in the Alum Bay section)	45
2. Dark greenish gray sand, like that at No. 3, Alum Bay section	25
3. Red and yellow sands	27
4. Dark greenish gray sand and clay, like those at 3, 4, 5, and 6, of the Alum Bay section	65
5. Red and yellow sands, like those of Alum Bay	30
6. Dark greenish gray sand and clay, in which were found *Venericardia planicosta, Cerithia, Sanguinolaria Hollowaysii,* and other London clay fossils	30
7. Variegated sands	6
8. Dark greenish gray sand and clay	186
At the points marked *h*, numerous small *Nummulites, Venus, Voluta, Cerithia,* and other London clay shells, were found; and at *h** large *Nummulites,* like those found at Bracklesham Bay, Sussex; also *Venericardia planicosta* and other London clay shells†.	
9. Variegated sands	10
10. Dark greenish gray sand and clay, like No. 8	45
11. Variegated sands, like those of Alum Bay	38
12. Greenish gray and brown clays	13
At *f* the clay was greenish brown with lignite. At *e* it had every appearance of London clay, abounding in numerous characteristic London clay fossils, including *Voluta luctator, Ostrea,* and teeth of a *Squalus.*	
13. Yellowish sandy clay without fossils	26
14. Greenish sand, similar to that of the Upper Marine in Colwell Bay, and containing apparently the same *Venus*	12
15. Yellowish sand without fossils	14

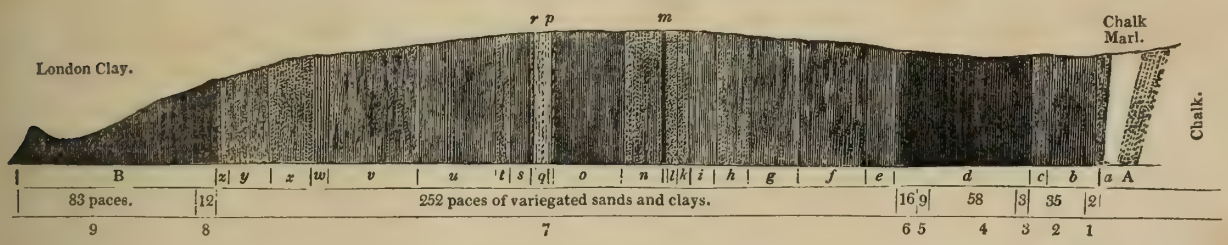
† Since the above passage was written I have visited Bracklesham Bay, on the opposite part of the Sussex coast, and carefully examined the beds in which the above-named shells abound; and from the perfect coincidence in colour and mineral character of the beds in the two localities, as well as in their zoological contents, I am induced to believe that the relative position of the Bracklesham Bay beds is that point of the series indicated by *h** in the White Cliff Bay section.—*February* 1841.

Beyond this point, the freshwater strata, abounding in *Potamides* and other characteristic shells, occupy the remainder of the space represented in the diagram.

The result of this examination is, that we find a complete alternation of the London and plastic clay formations throughout the whole space of 525 paces from the chalk to the break at *f e*, as we not only have abundance of London clay fossils at the place marked *e*, which corresponds with the great mass of that formation in Alum Bay, marked B in Mr. Webster's section, but we likewise find them at the points marked *h*, and at *h**. At *k* we again meet with the *Venericardia planicosta* and other characteristic shells †.

Having terminated our examination in White Cliff Bay, we next directed our attention to the corresponding out-crop at Alum Bay; but before proceeding to describe the beds, it is necessary to mention that the diagram No. 2. is copied from Mr. Webster's, in vol. ii. of the First Series of the Transactions. It includes the London clay B, which adjoins Headon Hill, and the coloured sands beneath it, down to the chalk marl *a*. I have inserted the letters of reference used by Mr. Webster in his paper on these formations, that reference may, if necessary, be made with greater facility to his descriptions of the strata. But as a detailed account of the whole of the beds described by Mr. Webster is not the object of the present notice, I have therefore divided the space into nine portions, commencing at the chalk marl and proceeding towards the London clay B; the following is the order of superposition: the beds in the section are in the inverse order to those in White Cliff Bay:

ALUM BAY.



	Paces.
1. Yellow sand	2
2. Variegated clay	35
3. Dark greenish gray sand, containing *Cancer Leachii*, etc.	3
4. Dark greenish clay, containing abundance of London clay fossils	58
5. Dark greenish gray sand, with veins of clay	9
6. Same sort of clay as No. 4	16
7. Variegated sands and clays without fossils	252
8. Gray and brownish clays without fossils	12
9. London clay, commencing with a band abounding with *Nummulites* and minute shells	83

† In the section of White Cliff Bay, p. 170, I have carefully abstained from tinting any part of the cliffs, excepting those portions which retain their original positions. The back cliff and disrupted portions are expressed by outline only.

In the first and second beds from the chalk marl, marked 1 and 2 in the second line of figures, no fossil remains were found, although a careful search was made for them from the beach upwards to nearly the turf-line at the top of the cliff. But upon examining the dark greenish gray coloured sands and clays included in the space numbered 3, 4, 5, and 6, we found in various parts the following well-known species of London clay fossils: *Venericardia planicosta*, *Cardita margaritacea*, *Mya intermedia*, *Ostrea* ——, *Venus* ——, *Cardium semigranulatum*, *Nucula similis*, *N. amygdaloides*, *Turritella conoidea*, *T. elongata* and *T. edita*, *Murex innexus*, *Buccinum desertum* and *Cancer Leachii*. The last fossil was found in the dark greenish gray sand near the chalk, and marked No. 3. in the diagram.

The whole of these specimens present the usual appearances of London clay fossils from Barton, Hampstead, etc. Upon carefully examining the strata of variegated sands and clays, extending 252 paces in length, we did not succeed in finding fossils; but at No. 8, where the London clay again makes its appearance, *Nummulites* and other London clay shells were found in great abundance.

XV.—*Description of the Fossil Trees found in the Excavations for the Manchester and Bolton Railway.*

By JOHN HAWKSHAW, Esq., F.G.S.

[Read June 5th, 1839.]

PLATE XVII.

THE fossil trees, to which the following observations refer, were found at Dixon Fold, Clifton, near Manchester, in making the excavations for the Manchester and Bolton Railway*. The largest of these fossils, No. 1. (see Pl. XVII.), was discovered about two years since (1837); and the others have been met with during the last three months, in excavating below the level of the rails to form a drain. No. 1. may have been taller than it now is, for being of a friable nature, a portion of its upper end might easily have been removed by the workmen before they discovered what it was. This observation is still more applicable to the others, as they are further within the line of railway, and the earth above them was removed in larger masses; but though they may have been shortened by this means, it is not probable that the imbedded remains of the original stems could have been more than a few feet longer than at present.

The section (fig. 6.) showing the stratification above the fossils, is in the direction of the line of railway, or from south-east to north-west; but the dip of the strata being nearly due south, at an angle of about fifteen degrees, the section passes obliquely across the dip. The dotted horizontal line is very nearly coincident with that of the rails.

The small bed of coal, the "two-feet mine" (see Section, Pl. XVII.) beneath which these fossils stand, occupies an intermediate place in the coal-field of the district. There are above the two-feet mine, in a thickness of about 130 yards, four other "mines" of coal, of an aggregate thickness of sixteen feet. The next subjacent coal-bed is forty-five yards below the two-feet mine. It consists of cannel coal,

* Care has been taken to preserve them, and they are now standing erect as when found; and being as much protected from the weather as their situation will admit, they will retain, for twelve months, at least, their original sharpness of outline sufficiently to render them interesting to the geologist. (1839.)

and is so irregular in dimensions, as to vary within a space of 600 yards from three to thirteen feet in thickness. Below the cannel are five or six other beds, all of which are worked within a few miles, so much does this part of the country seem to have been affected by physical derangement.

The five fossils are nearly in a straight line, and being parallel to the direction of the railway, they stand obliquely across the dip of the strata. In the direction of the section, a line drawn through the roots of the trees is conformable to the inclination of the strata; and in the direction of the true dip, this is still more plainly the case, the large spreading roots of No. 2. and No. 5. being quite conformable to the inclination of the stratum on which they rest; and the roots of the others are equally so to the extent to which they are seen, but being less exposed, they are not so striking in this respect. The whole of the stems stand very nearly at right angles to the plane of stratification. They are chiefly imbedded in a soft argillaceous blue shale, but that which surrounds the upper end of No. 1. is of a more siliceous nature. In the same plane as the roots, a thin stratum of coal has been found as far as the excavations have extended.

A still more remarkable circumstance is the great abundance of the *Lepidostrobus variabilis* about the level of the roots; for in the small excavations made around each tree, and just in the covering of the roots, more than a bushel of these fossils was found, chiefly in single specimens, forming the centre or nucleus of ovate nodules of bluish argillaceous shale. These specimens forwarded to the Society have been examined by Mr. Morris, who fully agrees in the above determination.

The whole of the fossil trees had a coating of coal, varying in thickness from a quarter to three-quarters of an inch; but generally it was so soft and friable, that, in removing the shale from around the trees, it crumbled off. The fossils consequently now appear to be almost decorticated; but the existence of the coaly envelope proves that they retained their bark wholly or in part when they were enclosed by their present matrix. Near the root of No. 5. a portion of this coal, about three-quarters of an inch thick, remains strong and firm. Its surface is marked slightly with longitudinal flutings, but they are very irregular in distance and direction.

The whole of the decorticated surface of the fossils has similar markings, the depression of the flutings being generally less than a quarter of an inch, and the intervening spaces about two inches broad; but there is considerable irregularity in this respect, and nearer the roots the slight furrows almost disappear. In several places, the surface of the cast of the trunk, and which evidently corresponds to that beneath the bark of the trees, bears distinct impressions of the woody fibre. This fibrous appearance is not generally longitudinal and parallel, but waving and irregular; resembling the peeled surface of our hard-wooded forest-trees.

The largest of these fossils (No. 1. of Pl. XVII.) is about fifteen feet in circumference at its base, and seven and a half feet at its top, and is eleven feet high. The next in size (No. 5. of Pl. XVII.) is less conical in shape, and measures seven and a half feet in circumference, and is six feet in height.

The fossil No. 2. has a shorter trunk; but is nine feet in circumference and two and a half feet in height. It has three large spreading roots which are nearly four feet in circumference at their commencement, and which, after extending six feet from the trunk, separate into eight arms or roots. The other two fossils (Nos. 3, 4.) are of smaller size, being three feet and five feet in height respectively, and six feet in circumference; and their roots seem to extend but a short way into the soft shale and coaly matter. The roots of No. 5, as far as exposed, are solid and strong and four feet in circumference, and being quite unbroken, they have every appearance of being prolonged to a considerable distance from the trunk of the tree. There is no reason for supposing that the roots of No. 1. are not equally spreading, but the position of both these fossils rendered it difficult to follow them further. None of the drawings show the roots so perfectly as they are seen *in situ*; for all the fossils, except No. 1, being considerably below the level of the rails, and standing in deep holes, the artist in drawing them had to take a bird's eye view, which rendered it difficult to delineate them perfectly.

The description which I have given of the appearance of the fossils and their situation, will, I hope, with the assistance of the drawings, be understood; it therefore only remains to add a few general observations.

I have already mentioned, that the roots of the trees were covered with a thin stratum of coal: by excavating on the opposite side of the railway, I found that this seam (eight to ten inches thick) extended under the railway, and to a distance therefore of ten yards at least from the trees; and it is likely that it ranges much further. It probably represents what was formerly the vegetable covering of the spot on which the trees stand. It is true, that the fact of the trees having been found erect, would not prove that they grew there; but that they now stand, (broken and fossilized,) on the very spot where they once flourished, is rendered exceedingly likely by the circumstance of all of them being perpendicular to the stratum on which they rest. Having, during a residence in South American forests, been accustomed to see trees torn by the roots and carried to and fro, I find it difficult to conceive that, even once in ten times, a tree so transported and replanted (if I may use the expression) in another place would be left quite in a perpendicular position. There is, perhaps scarcely ever, in trees of large girth, such a preponderance of weight in the roots as to ensure more than obliquity of position in deposition after such a removal; for the earth torn up with the roots is soon washed off; and that five trees near together should all have been thus placed quite

perpendicularly, would be a much more marvellous thing than that they once grew where they now stand.

Admitting them to have lived where they have been discovered, and considering as a general rule that trees grow perpendicularly to the horizon, these fossils would indicate, that the strata of the coal formation on which they rest, were formerly in a plane parallel to that of the horizon, and have since been inclined to the angle at which they now lie.

With regard to the species of the trees, there is a difficulty in deciding upon it. The friable and disintegrated state of the coaly envelope gave little or no clue to the external markings of the bark. The great size of the stems and the appearance of flutings would lead to the belief that they are specimens of the *Sigillaria pachyderma*; but this opinion depends chiefly on the flutings for its support, and they are perhaps too indistinct and irregular to be very decisive evidence.

Could the fossils be shown to be specimens of *Lepidodendron Sternbergii*, it would be an interesting fact, in conjunction with the circumstance of the ground around them being strewed with fossil specimens of *Lepidostrobus variabilis*, which M. Adolphe Brongniart was of opinion belonged, as organs of fructification, to a *Lepidodendron*. How far the absence of the rhomboidal scars in the lower part of specimens of so great dimensions should weigh against such a supposition, is for more competent fossil botanists than myself to determine.

Manchester, May 1839.

XVI.—*Further Observations on the Fossil Trees found on the Manchester and Bolton Railway.*

By JOHN HAWKSHAW, Esq., F.G.S.

[Read February 27th, 1840.]

SINCE the reading of my first communication on this subject, another fossil tree, about three feet in length and three feet in circumference, has been found on the opposite side of the railway. It stands on the same thin stratum of coal as the others, and, like them, it is perpendicular to this stratum. This additional fossil tends greatly to confirm the view already taken, that the trees now stand on the precise spot where they grew. If there be some difficulty in conceiving that one detached and erratic tree could be placed and left quite perpendicular on the surface of an ancient formation, there is vastly greater difficulty (in my mind almost an insuperable one) in conceiving this condition to belong to six trees, all within a few yards of each other. But even of the precise position in which they stand, no written account can convey a conviction as to their being *in situ*, at all equal to that which forces itself on the mind from a single glance at the fossils themselves; and for precisely the same reason, that a mere statement of five or six broken stems of trees standing in the middle of a green field, would convey nothing like the certainty of their having formerly grown there, that would be derived from one glance at the objects themselves. As far as I am aware, not one of the many geologists who have inspected these fossils has felt a moment's hesitation in considering them to be now on the same spot where they grew. This point being as I conceive settled, I will proceed to add a few particulars and observations which appear to me to be applicable in some degree to these and similar fossils.

In the tropical parts of South America, I have observed several instances of trees which had been cut down or broken off near the ground, becoming hollow by the rapid decay of the wood; little more being left than an outer shell, consisting chiefly of the bark, which had resisted decay better than the wood. The cases to which I refer, were of dicotyledonous trees, having a proper bark; and I have noticed this peculiarity more frequently in trees of that class than in Mono-

cotyledons, excluding of course the bamboos, canes, etc., which are always hollow. For instance, in the Palm tribe, which near the coast is frequently interspersed with forest trees, I do not remember to have met with an instance. The rind or outer covering of this magnificent class of plants is of considerable thickness, and has generally a density and a structure which seem to defy decay; while the interior or pithy part possesses antiseptic qualities whereby it is enabled to resist decomposition much longer than the interior or proper wood of many of the tropical forest trees growing in low and moist situations.

Sometimes the portion remaining in the ground of these dicotyledonous trees, including the strong roots and a short piece of the stem, presented very much the appearance of the founder's mould when he has withdrawn the pattern from the sand, before the metal is run in to form the cast. By this kind of decay a cavity was left, from which might have been taken a fac simile of the lower portion of the tree, with the strong, diverging roots; and in nearly all cases, this cavity was lined with the whole or with remnants of the bark. Deceived by their outward appearance, I have stepped upon similar trees which were prostrated on the ground, and which, unable to resist the pressure, gave way beneath my feet, and allowed me to sink into what was apparently a massive tree, but which in reality was only a hollow cylinder.

So often do these decayed stems occur in the low and hot forests of the coast of South America, that dangerous accidents frequently happen in consequence. Many of the rude and temporary bridges which had been thrown over narrow streams and ravines by Englishmen, who wanted the leisure or the knowledge to select a proper material, have often suddenly given way, though they had been erected perhaps only twelve months. Formed of trunks of trees, the outward appearance afforded no sign of the inward decay; and the first notice the unwary traveller had of the instability of the bridge, was, his being precipitated into the stream below. The bark of these trees had changed but little, while of the interior nothing was left except dust and a few decayed remnants, which crumbled beneath the lightest touch.

The forests in which I have observed these appearances are in Venezuela, on the shore of the Carribean Sea, between the eighth and tenth degrees of north latitude, and the sixty-fifth and seventieth degrees of west longitude. The only analogous appearances we have in this country, are produced by the dry-rot, which sometimes destroys the interior of timber with great rapidity, leaving an exterior crust; but these appearances are neither so frequent nor so striking. In the tropical forest a few months suffices to destroy the interior of the largest tree, by a process which, instead of being of a vegetative nature, as the dry-rot is in this country, appeared to be of a fermentative character commenced in the juices of the tree, and which

dissipated in volatile gases that which just before had presented a solid form. The great heat and excessive moisture of these forests appear well calculated to hasten such processes; and in a manner which persons who have always lived in more northern climes can scarcely conceive of;—whether these processes originate in chemical action, or in the growth of fungi, or in both combined.

Cases of this kind were met with most frequently in the low and flat lands, which are equally adapted to the growth of the tallest forest trees and the most majestic palms, and where, from the deep wet soil and excessive moisture, all the subordinate vegetation consisted of canes, bamboos, and minor palms. Such tracts would be most easily submerged, and are most analogous in character to our coal-basins. The filling-up or undergrowth of these districts being soft and green, it would be less likely to leave permanent traces of its existence behind. The palms would form but a small proportion of the whole, and a large number of the forest trees rendered tender and friable by rapid decay would be dissipated and lost in the surrounding nucleus, leaving little more than specks of carbonaceous matter, to tell of their former existence. Supposing the vegetable covering of the spot on which the forests grew, was thick enough to form that which to future ages would be a seam of coal, the decayed trees would be incorporated and mixed up with the mass of vegetable matter, mingling like the dust of former generations with their kindred dust around. These observations may perhaps somewhat elucidate why so few distinct fossil remains of a large size are found in our coal-measures, and the absence of which has not unfrequently struck me as peculiar, considering the myriads of forest trees which must have constituted part of the vegetable kingdom at the time of the formation of our coal-deposits. The fossil trunks of trees are comparatively rare. *Calamites*, if they resembled the canes or reeds of tropical forests, from their harder texture, might be expected to have more frequently left the traces of their forms behind; but if they belonged, as seems likely, to another class of plants of a softer structure, the question again arises, why are they more numerous than the fossil remains of trees? Giving full force to what I have stated as to the rapid decay of many forest trees in tropical climates, it may yet be remarked, if coal is to be looked upon as the debris of a forest, we ought to find more numerous traces of trunks of trees in our coal-basins. The difficulty is a great one, and it is only perhaps by allowing the original of our coal-seams to have been a combination of vegetable matter analogous to peat, that the difficulty can be solved. Few trees would grow in these situations; and we might expect to find them, as we do find them, few in number, and isolated in position. The Flora of our coal-formations would then be representatives of almost naked mosses; and the remains of vegetable forms we most frequently find would only, as has been already advanced by Professor Lindley, be confirmative of the

antiseptic qualities of their original nature, not of the number or importance of their particular genera, at the time of their deposit.

Whatever opinion may be drawn from that which is conjectured in the foregoing statements, there is one conclusion that will be obvious; viz. that though fossil remains may be found filled with a mechanical deposit, and containing traces of other vegetables, yet this condition does not prove that the stems were formerly hollow, nor even render it the most likely hypothesis; for they may have been what are usually termed hard wood trees, notwithstanding this circumstance.

Manchester, January 1840.

XVII.—*On the Siliceous Bodies of the Chalk, Greensands, and Oolites.*

By J. S. BOWERBANK, Esq., F.G.S.

[Read March 11th, 1840.]

PLATES XVIII. and XIX.

THE singular forms presented by the tuberous masses of flint found in the upper chalk have long induced naturalists and geologists to imagine that their forms were derived from Alcyonic or spongeous bodies, but I am not aware that this has hitherto been demonstrated to be the actual fact. Professor Ehrenberg's observations on siliceous bodies first induced me, in common with many other persons, to cause thin slices of flints to be made, with the intention of procuring specimens of *Xanthidia*; and in the examination of these slices I was struck with the frequent occurrence of small patches of a brown reticulated tissue, which always presented nearly the same appearance. The occurrence of this tissue, combined with the circumstance of finding spicula exhibiting nearly the same form and size, and always occurring in about the same proportion, along with numerous foraminated shells and other extraneous bodies, strongly induced me to believe that the brown reticulated tissue was a portion of the remains of the organized body, the shape of which was represented by the flint nodules; and the indications thus observed equally inclined me to believe, that if these flints were fossil organized bodies, they would almost inevitably prove to be sponges. With these views I commenced the investigation of the flints of the chalk, and as a preliminary measure I first examined, in a cursory manner, thin slices of flint nodules from various localities, especially of those from the neighbourhoods of Gravesend and Brighton, and from Hertfordshire, Norfolk, and Wiltshire; and in all of them I found a perfect accordance in the structure and proportion of the reticulated tissue, and of the spicula before alluded to, and also in the occurrence of *Xanthidia* and *Foraminiferæ*. This similarity in the structure of the flints from all the above localities, renders it unnecessary to detail the results of each examination separately. I shall therefore confine myself to the description of what may be observed, by a

careful investigation, in any chalk flint, without reference to the spot from which my specimens may have been procured.

When thin polished slices of the common tuberous flint of the chalk are prepared by a lapidary, mounted upon slips of glass, and subjected to examination, as transparent objects, with a microscopic power of about 120 linear, it will be observed, that the appearance presented to the eye is similar to that of a thin stratum of a turbid solution of decomposed vegetable or animal matter, containing fragments of extraneous bodies, mixed with small foraminated shells, spicula of sponges, and minute animalcules; especially of that highly interesting and beautiful genus, *Xanthidium.* Amid this heterogeneous mass there are frequently to be noticed fragments of the brown reticulated tissue, to which I have before alluded; and occasionally, if the slice be from near the surface of the flint, these patches of brown spongeous substance are comparatively of considerable size, and are dense and opaque. In this state, and by this mode of examination, the reticulated form of the structure can only be perceived at the edges of the mass. When it occurs in this well-preserved form, which is indicated to the unassisted eye by the appearance of rusty brown coloured spots on the flints, it is best examined by placing a small round black patch, about two lines in diameter, behind the spot to be examined; and then illuminated by a leiberkuhn; and viewed with a power of 120 linear, it exhibits the characters represented in fig. 1, Pl. XVIII. In that specimen, which is from a flint procured at Northfleet, near Gravesend, the structure is remarkably well preserved. The mass of the sponge appears to consist of numerous cylindrical contorted canals, which, from the uniformity of their size and the minuteness of their diameters, would appear to have been the in-current canals of the sponge. Occasionally orifices of a considerably larger diameter are dispersed in the mass, and have every indication of having been the large ex-current canals. The walls of these canals present the appearance of having been formed of a thin glairy network, bearing a strong resemblance to the reticular substance of the common freshwater sponge of the rivers of England. Amid the mass are found spicula, comparatively speaking, very sparingly dispersed; and minute foraminated shells of many species, imbedded in a precisely similar manner to what we observe on a larger scale in the recent Mediterranean sponge of commerce*. Very frequently, when but little of the reticulated substance of the

* When the above passage was written, it was generally considered that the Keratose sponges were destitute of spicula; but I have since ascertained that they are occasionally found imbedded in the larger horny fibres of the sponges of commerce, and in numerous other sponges of the same genus from New South Wales; and I have described the mode in which they occur in a paper read before the Microscopical Society, Jan. 27, 1841. Since the publication of these facts, I have also ascertained, from the examination of an Australian species of Keratose sponge which was brought by Mr. Gould from Swan

sponge remains, its former presence is indicated by the siliceous matter exhibiting the aspect of a congeries of gelatinous globules, evidently arising from the silex having been moulded by the tissue amid which it was deposited; and the gelatinous molecules, when traced to the edges of small patches of the spongeous texture, are found to agree in size and form with the orifices of the supposed in-current canals. In other cases, no indication of the former presence of the organized structure of the sponge remains; but its previous existence is proved by the mode in which the spicula, the foraminated shells and the other extraneous matters are found suspended, equally in all parts, and not precipitated to one particular portion of the flint, which would have been the case, had the space in which they were deposited been a mere hollow, arising from the imbedment and subsequent rapid decomposition of the body which has given rise to the peculiar form assumed by the mass; but, on the contrary, their continued suspension in their natural position indicates that the organized tissue in which they were entangled, retained its form and texture sufficiently long to allow of the infiltration and perfect fossilization of these interesting remains, in their original places. Had we no other evidence, the nature and position of these remains would have strongly indicated the former spongeous nature of the tuberous-shaped flints of the cretaceous beds. If the chalk be carefully washed from the exterior of a flint with a soft brush, and a portion of that surface be examined as an opaque object by direct light, with a microscopic power of about 50 linear, we shall observe it to present a peculiar saccharine appearance, with occasionally deep circular excavations; and with small fragments of shells and other extraneous matters, partly imbedded in, or only slightly adhering to, its surface. If the surface of the flint be further cleansed from the chalk, by immersion in dilute muriatic acid, until effervescence ceases, the deep circular orifices will frequently be seen to have spicula projecting from their sides; thus strongly pointing them out as having been, in all probability, the mouths of the larger ex-current canals. If small pieces, about a quarter of an inch in diameter, be now selected, presenting the roughest and most saccharine aspect, and these be illuminated by a leiberkuhn, and examined with a microscopic power of 120 linear, under favourable circumstances, it will be seen that the surface is formed by a complex mass of small contorted tubuli, the apices of many of them being furnished with a minute perforation, as represented in fig. 2, Pl. XVIII.* The tubuli on the surface

River, preserved in spirit immediately after being taken from its place of growth, that siliceous spicula occur in great numbers in the fleshy substance that fills up the horny network of the sponge in its live state. It therefore ceases to be an anomaly, as it might have hitherto been supposed, that siliceous spicula should be found imbedded in the fossilized remains of a Keratose sponge.—*March* 1841.

* A similar tubular structure of the fibre exists in the recent *Spongia fistularis*, described and figured by Dr. Grant in vol. ii. of the New Edinburgh Philosophical Journal.—*March* 1841.

of the flint stand boldly in relief from the more solid portion of the white crust, which surrounds the dense and semi-transparent mass. If we give but a slight consideration to the circumstances under which these bodies have been probably buried, we shall at once perceive that the characters exhibited by the surface of the flints, and the state of the tissues at this part, are exactly such as we should naturally expect to be the case; for if a modern sponge of a close texture be immersed in water, in a tranquil situation, and a gradual deposit of calcareous silt, of small specific gravity, were to take place upon it, the deposited matter would penetrate the substance of the sponge to a very slight extent only, while the interior of the space would remain filled with pure or nearly pure water, and the portions of its structure thus embraced by the calcareous deposit would be protected to a great extent from the operation of other agents; and we might reasonably expect that, although the minute hollow tubuli might be assailed from the interior of the mass by a second and more fluid matter, and thence become silicified, yet that the space between them would be occupied by the matrix in which they were imbedded: and this is exactly what appears to have taken place during the process of the fossilization of the sponge of the common flint. The structure, both internal and external, and the peculiarities thus described, are common to the great mass of the tuberous flint nodules of all the localities of the chalk formation of England from which I have been able to procure specimens, and under circumstances where we should have scarcely expected them to have been preserved.

The structure and other characters of the layers of tabular flint are in perfect accordance with those of the nodular flints. *Xanthidia*, spicula, and foraminated shells are dispersed with equal abundance in its substance. The upper surface resembles in every respect that of the flint nodules, while the under one presents, even to the unassisted eye, a still more strongly marked spongeous aspect. Its general appearance is that of a sponge which has been built upon an irregular surface, and has followed the whole of the sinuosities. The great ex-current canals are larger and more numerous than usual; and the spicula are more abundant, frequently projecting from the surface, while the *Foraminiferæ* are attached so abundantly to it, that upon a superficies of an inch and a half square, I have counted upwards of twenty specimens of various species, some of which were attached only by a minute portion to the mass, precisely in the manner in which small bodies are frequently attached to recent sponges. It would thus appear, that the only difference between the tabular and other forms of flint was, that at the period of the formation of the tabular flint the original sponge was built upon a firmer and less changeable surface than usual; and that under these circumstances it had obeyed its natural instinct, that of coating over any mass upon which its gemmule might have chanced to settle, in a manner precisely analogous to the habits of the freshwater

sponge of our rivers, and to many other parasitical species which are inhabitants of the sea at the present period. Wherever the sponge had settled upon a shell, or *Echinus*, this habit of coating the body it was based upon is strongly illustrated; but as the substance thus built upon was probably to a small extent immersed in the silt or mud, we rarely find more than half or two-thirds of the surface enveloped, and from this circumstance it is, that we detect in chalk fossils so many which are more or less imbedded in flint; and among these, instances are found, varying from cases in which the sponge-gemmule had not long settled and commenced developing itself, to where it had grown to such an extent as to have exceeded many times the size of the base, upon which it most probably at first settled. The great mass of nodular chalk flints does not exhibit any indication of a base, except in those instances where extraneous substances appear upon the surface; but this may be readily accounted for, when we consider, that probably, in the first instance, the gemmule was attached to some minute fragment of a shell or other substance, and that its further development took place while it was merely recumbent on the silt or mud; in the same manner as we occasionally find specimens of modern corals, etc., without any apparent base, the original attachment having been built over, after it had become separated or liberated. In one specimen of flint in my possession, the sponge appears to have been torn or injured, nearly at its middle, as a broad and distinct band or collar has been built round it, evidently with a view of repairing the injury and strengthening the substance at the weakened part.

The perpendicular and oblique veins of flint, found in the chalk cliffs between Brighton and Rottingdean, and described by Dr. Mantell, present precisely the same internal characters as the tabular flint and the common tuberous nodules. The external characters are also similar to those of the tabular flint. If we observe these veins *in situ*, we shall frequently perceive, that the whole of their substance is not of uniform density, but that there are often, near the middle of the vein, parts where the two interior surfaces have not united, and that the spaces are generally filled with chalk. If this chalk be carefully removed or dissolved by diluted muriatic acid, the internal surfaces present the same appearances which have been described as characterizing the exterior of the ordinary flint nodule and the aspect of the whole is precisely such as we should expect to find, if the two sides of a fissure in a rock were covered by our common freshwater sponge, or one of similar habits; and the two outer surfaces had been built towards each other and had joined in some parts, while in others they had approached, but had not united. The sides of these flint veins are not studded with numerous species of *Foraminiferæ*, like the under surface of the tabular flint, but from the position

in which the flint veins have been built, it is a natural consequence that this should not be the case.

Having thus satisfied myself that the common tuberous flints, the horizontal tabular flints, and those forming perpendicular or oblique veins, were all produced by the same agency, and having observed the frequent occurrence of the partial imbedment of shells and other extraneous bodies, I was naturally led to infer, that in all probability the interior casts of *Echinites* and similar bodies, which are frequently found to be filled with flint, were also produced by the same agency; I therefore procured numerous specimens of silicified Echinodermata, and their examination strongly corroborated this supposition. Some of them were not entirely filled with flint; in one case a small portion only was siliceous, in others two-thirds or three-fourths of their interior were so occupied, while the remaining space was filled with chalk. Upon clearing away the chalk from this part of the specimen the flint never presented an even surface, such as would have been produced had a portion of fluid matter entered through the ambulacra and subsided, as water or any similar liquid would have done; but, on the contrary, the surface was always undulated, and frequently projected considerably above the surrounding parts, more especially near the side of the shell, against which it was frequently built in semi-cones or columns, and in the space thus unoccupied by the flint there was always included one or both of the large orifices of the shell. The undulated surface of the flint thus concealed within the Echinite presents exactly the same organic characters which are observed on the flint nodules. Most frequently the Echinite is filled with the flint; and the animal having thus built its prison full, has usually perished from want of sustenance; at other times it has survived this incarceration, and has grown out of one or both of the great orifices of the shell, and has then, in some cases, increased to a very considerable extent. On the exposed surface of the whole of these, whether it be only to the extent of a slight convex projection from the orifice of the Echinite, or to a considerable mass, an accordance will be found with the organic characters before described.

If some of the specimens of *Galerites* and *Spatangus*, which are filled with flint, be placed in diluted muriatic acid, and the whole of the shell be removed, the appearance presented by the siliceous casts will still further corroborate the opinion of their spongeous origin. Occasionally it will be found, that the ambulacral orifices of the shell have been filled with fine threads of silex, and that these are based upon the cast; but more frequently we shall find, that opposite to each of these numerous minute orifices, there is a small but deep depression, the interior of which presents the usual characteristic surface observed on all flints, and the minute tubuli will be seen as boldly projecting at the bottom and around these small exca-

vations, as upon any of the exposed surfaces of the flint. In these cases the ambulacral orifices of the shell have evidently been used by the sponge as so many inlets to admit the streams of water which were necessary to its existence; and the depressions thus produced directly beneath them were clearly intended as a means of facilitating this operation. On the surface of the cast, in the immediate neighbourhood of the two large orifices of the shell, there is frequently a series of channels, which have evidently been left by the sponge for the same purpose as the depressions opposite the ambulacral pores, and the bottoms and sides of these channels exhibit the sponge tubuli in a like manner.

It frequently occurs in the *Echinites* which are filled with flint, that portions of the shell have been replaced or infiltrated with silex. In all these cases that I have seen, the silex presents a stalactitical or chalcedonic form, and never exhibits the spongeous texture. Very frequently, however, thin laminæ of spongeous texture are found to have been built between the plates of the Echinite, where they have happened not to have been quite in contact; and in these laminæ the tubuli are as beautifully distinct as in the most favourable portions of the mass of the cast. If the surface of the cast be microscopically examined, we shall frequently observe that the flint has not been in such a state of contact with the shell as a cast from a fluid material would be supposed to present; for although the boundary of each plate is well marked, the areas of their impressions exhibit such a view of the tubuli of the sponge as we might naturally expect to find where numerous minute tubes have been built against a flat or slightly concave surface. Sometimes the sponge has grown round the interior of the shell, and has left a hollow near its centre; and occasionally the sponge appears closely approximating, yet not quite adhering, to the inner surface of the Echinite. In these cases, a thin film of chalcedony is frequently spread over the organized surface of the sponge, which in a specimen in my possession is in several places to be seen through small breaks in the film.

The results arising from the various forms of flint which have been described, induced me to believe that the flint cases enveloping the numerous and beautiful specimens of sponges and corals of the Wiltshire chalk would probably prove to have originated in a similar manner to the forms of flint before described. I therefore requested Mr. John Baker of Warminster, who collects large quantities of these beautiful fossils, to furnish me with some, the interior surfaces of which had not undergone the usual process of washing and brushing. Having cleaned these carefully, by pouring into them a small stream of water, I observed spicula projecting from all parts of the interior surface; and the same appearance was exhibited to a greater or less extent in more than twenty specimens which I examined,

however different in character the sponge or coral enclosed within the flint might have been; the spicula appearing to have no reference whatever to the bodies thus enclosed, none of them being found upon the included body, but only upon the case. When microscopically examined, the interior surface of these flint-cases presented in every respect the same appearance as that exhibited by the under surface of the tabular flints; and there are generally fragments of minute corals, small *Terebratulæ* and other shells attached to the inner surface; and in the same case there are frequently two, and sometimes three, different species of coralline or spongeous bodies; thus proving that these beautiful Wiltshire specimens are merely extraneous bodies which have been built over and enveloped by the common coating sponge of the chalk. Many of the contained bodies also present evidence of their having been exposed some time previous to being thus enveloped, as we frequently find upon their surfaces patches of *Flustra*, which are in the habit of seating themselves upon dead or inorganic matter. Thin sections of the cases of the Wiltshire fossils exhibit the characteristic *Foraminiferæ* and spicula, as well as the common species of *Xanthidia*.

It may be objected to this mode of accounting for the envelopment of sponges and corals by the common casing sponge of the chalk, that the enclosed bodies are usually almost in the centre of the flint, which would not be the case, if they had been dead specimens lying at the bottom of the ocean at the time they were built over; but in reply to this it must be remembered, that although dead specimens, they most probably retained the position in which they lived until the extraneous mass surrounding them might alter their centre of gravity, when they would fall on one side, and their bases would then, in all probability, be built over in the same manner as the remainder of the mass. In many of these bodies, also, there are portions of the enveloped sponge or coral which have never been invested, and in numerous instances there are orifices remaining in the flint-cases through which the roots of the enclosed body have passed out, and which were probably preserved from being built over, either by being buried in the soft mud, or by being attached at the bottom of the ocean.

The tubuli of the flint-sponge are very minute: an average of the measurements of four well-defined tubes upon the surface of a common flint gave the $\frac{1}{1268}$th of an inch as the diameter; the smallest of these was the $\frac{1}{1575}$th, and the largest the $\frac{1}{800}$th of an inch in diameter. In the cast of an *Ananchytes*, five which were measured gave an average of the $\frac{1}{652}$nd of an inch; the smallest of these being the $\frac{1}{778}$th, and the largest the $\frac{1}{510}$th of an inch in diameter. In the cast of a *Galerites albogalerus*, in which they were in a very beautiful state of development, a measurement of seven gave the $\frac{1}{855}$th as the average; the largest being the $\frac{1}{752}$nd, and

the smallest the $\frac{1}{980}$th of an inch in diameter. The tubuli in this specimen were hollow; and one of them, which had been broken at a right angle to its axis, gave the following measurements: external diameter $\frac{1}{980}$th, internal diameter $\frac{1}{1852}$nd of an inch; thickness of the substance of the tube $\frac{1}{4167}$th of an inch. In their size and proportion the tubes agree very nearly with those of the recent sponges. The average diameter of the fibre of the common sponge of commerce is about the $\frac{1}{1130}$th of an inch, and in the sponge from New South Wales the diameter varies from the $\frac{1}{971}$st of an inch to the $\frac{1}{472}$nd. The spicula are large in proportion to the other parts of the tissue, very frequently exceeding the eighth or tenth of an inch in length. They are thinly scattered, and usually acicular in their form; but sometimes they are forked or branched, but this is comparatively a rare character. They do not occur in fasciculi, as in *Halichondria*, but are usually solitary, or a few are grouped together. They are mostly of an elongated, spindle-formed shape and somewhat curved, as represented in fig. 3, Pl. XVIII., which exhibits them in their natural position, on the interior surface of a flint from Wiltshire; or in fig. 4, Pl. XVIII., which gives a series of the largest of them, separated from the white friable siliceous matter from the interior of one of the Wiltshire flints.

The results arising from the examination of the flinty bodies of the chalk induced me to believe that the cherts of the greensand formations and of the oolites would probably prove to be of similar origin. I therefore examined thin slices of specimens of chert from the upper greensand pits of Fovant in Wiltshire, in the manner pursued in the investigation of the flints; and I found, as I expected, the result to be of a similar description; but in this substance the spongeous fibre is of a much coarser texture than in that of the chalk-flint, and the interstices of the network very much larger in proportion. The imbedded extraneous matters are also of a larger description, such as small fragments of apparently very fine branched vegetables, etc., in addition to *Xanthidia* and other small organic bodies. The form and mode of ramification of the tubular structure approaches nearer to those of the fibre of the common Mediterranean sponge than in the flint spongite. The tubes are seen dispersed in about an equal proportion through the whole mass of the chert. They are very pellucid, and would probably escape observation, if it were not that their surfaces are covered with a short downy-looking structure, which gives them very much the appearance of minute portions of a very transparent *Fucus*, when viewed as a transparent object, with a microscopic power of fifty linear. Sometimes, but very rarely, portions of the tubes remain hollow, and they then display a very distinct and characteristic appearance, such as that exhibited by fig. 1, Pl. XIX., which represents a portion of the tubes under these circumstances, as they appear when viewed as opaque objects, with the aid of a leiberkuhn. The average measurement of five of these tubes gave a diameter of

$\frac{1}{344}$th of an inch; the largest being the $\frac{1}{276}$th, and the smallest the $\frac{1}{484}$th of an inch.

The cherty nodules from the upper greensand of Shaftsbury presented appearances exceedingly similar to those observed in the specimens from Fovant. The black and semi-transparent mass of chert in the centre was surrounded by a coating nearly an inch in thickness, which had the appearance of agglutinated sand; and the outer surface of the coat assumed an eccentric tuberous form, very similar to that of the chalk flints.

Upon microscopically examining the structure of this coat, as an opaque object, numerous contorted canals of various sizes were observed, and beautiful green spicula were visible imbedded in considerable numbers in the mass. It would therefore appear, that the same process went forward during the imbedment of this sponge, which we have supposed to have taken place during the envelopment of the sponge which originated the chalk flints; but the sponge, in this instance, being of a coarser and more open nature, it has been penetrated by the surrounding fine sandy matter to a greater proportionate depth than in the case of the chalk flints. Two casts of *Spatangus* in chert, from the upper greensand pits at Shaftsbury, presented results analogous to those obtained by the examination of the flint casts from the chalk; the surfaces exhibiting numerous tubes and spicula, which corresponded in size and appearance with those shown in the thin sections represented by fig. 1, Pl. XIX., so that little doubt can exist of the formation of these casts being similar to that of the chalk flints.

Upon examining in the same manner a number of slices from a great variety of masses of chert belonging to the greensand of Lyme Regis, nearly the same appearances were presented as those afforded by the chert of the upper greensand of Fovant. A group of tubuli are represented at fig. 2, Pl. XIX.: and their size, mode of disposition, as well as general character, so closely resemble those of the upper greensand, that there is strong reason to believe the sponge to have been of the same species, or very closely allied to it; and it was only when they were examined as transparent objects, with a power of 360 linear, that I could detect any evident difference. Under these circumstances the tubes of the former present the semblance of a mucous surface, with minute irregular particles of opaque matter adhering to them, while the tubes of the latter exhibit an appearance as if minute patches of a thin epidermal membrane had been partly detached from their surface; but this trifling variation in the appearance of the organic structure may probably have been caused by a slight difference in the circumstances attending their fossilization. The tubuli vary in their size to about the same extent as those of the upper greensand spongite, but their average diameter is as nearly as possible the same.

The dimensions and external form of the masses of chert in the greensand of Lyme are widely different from those of the upper greensand, and would seem to indicate a specific difference, but the resemblance of their internal structure evinces a very close alliance in every other respect. Two specimens of chert from the oolite, one being from the Tisbury limestone and the other from the Portland, afforded similar strongly-marked evidences of organized structure; but with this difference, that in these there appeared to be a greater quantity of the cellular structure of the sponge preserved than in any of the former instances; and the appearances afforded by the structure, in both cases, were nearer to those of the freshwater sponge than any of the fossil sponges of the chalk or greensands, with the exception that there were fewer spicula than in the recent freshwater species. When small portions of dead and decomposing freshwater sponge were immersed in Canada balsam, and examined microscopically in the same manner as the siliceous slices, the appearance was so similar to that of the fossils, as to prove at once that the oolitic cherts derived their origin from decomposed spongeous masses*.

* With a view of confirming the above statement, I visited, during the summer of 1840, the Island of Portland and the greensand formation at Blackdown. In the former district I found the principal source of the numerous masses of chert abounding in the great talus beneath the cliffs of the western side of the island to be an immense band of chert, which may be readily traced almost the entire length of the western cliffs, and is situated about one-third from the upper surface, of the whole height of the cliff that is apparent above the talus. This stratum varies from three to five feet in thickness, and upon a close examination it is found to be composed, not of one uniform mass of chert, but of thick tortuous branches, if I may be allowed the expression, which ramify and wind in all directions, leaving intervals between them of nearly their own dimensions, and filled with the same material as that of which the surrounding Portland stone is composed. This is decidedly not the form of a merely mechanical deposit of siliceous matter, but it resembles closely, in every respect, the arrangement which large spongeous masses assume when growing thickly strewed at the bottom of the ocean; for although sponges, under such circumstances, in their young state, are separate and distinct from each other, yet it is well known, that it is their habit, when they grow to such a size as to approach and touch each other, to unite and form vast masses, which spread over a great extent of surface. I examined the numerous fresh vertical sections, frequently eight or ten feet in length, afforded by the masses which had recently fallen from the face of the cliff, and in all these the oolitic material was observed permeating the whole of the mass in an irregular and tortuous direction. In the sections of the chert thus examined a white, clouded appearance was very generally observable, and upon examinination was found, in every case, to be caused by the remains of a spongeous tissue, identical with that before described as occurring in the specimens of chert formerly examined. This structure may be indistinctly seen with a good Coddington lens, but to obtain an accurate idea of its nature, it should be viewed as an opaque object with a leiberkuhn, and an achromatic microscopic power of two hundred linear; and it is only by such an examination that its true character can be observed with the greatest advantage. In the strata of Portland oolite, both above and below this great bed of chert, large tuberous nodules of chert are frequently found. These resemble very much in their external characters the irregular cherty nodules described as occurring in the upper greensand of Fovant and other localities. The interior presents the same structure and ap-

Dr. Grant, in his 'Outlines of Comparative Anatomy,' in treating of the *Poriphera*, concludes his observations by saying, "The abundance of siliceous needles in the skeletons of the lowest *Poriphera* assists in their conversion into flint, when their remains have been exposed for ages in chalk or other strata traversed by silicifying percolations" (p. 9). I am strongly inclined to believe, that the siliceous spicula, in the cases under consideration, have not influenced the deposition of the flint in so great a degree as we may at the first view be inclined to believe, for there are circumstances attending this accumulation of the siliceous matter which are exceedingly curious in their nature. We find that the deposit of the silex is in no case limited or determined by the immediate presence of the spicula, nor do we observe, when thin sections of these bodies are viewed with the microscope, that the spicula have operated as nuclei from which the silex has radiated, in the form of needles or crystals driving the surrounding bodies before them, in the manner that we so frequently observe in silicified wood; while, on the contrary, we frequently notice in the chalk-flint spongites, that portions of the large ex-current canals are not filled with silex, and the spicula are seen projecting into them without even the slightest incrustation of siliceous matter upon their surface. On the contrary, the siliceous is in all these cases bounded by the extent of the animal matter of the sponge. Whenever a single tube, or a thin layer of tubes, has been projected from the mass, although it may have been imbedded in the chalk, there does the siliceous matter appear to follow, as if under the powerful influence of some species of elective attraction, with the laws of which we are at present unacquainted, but which I trust will hereafter become a subject of investigation to some of our able chemists; and this attraction of the silex to the animal remains is so complete, that the chalk adhering to the surface of the flint is as free from siliceous particles as that which is far removed from the mass; and a hundred

pearances which we observe in the corresponding parts of the siliceous portions of the great chert-bed. The clear cherty nucleus is enveloped by a thick coating of spongeous structure, which has been rendered opaque by a partial infiltration of the surrounding material. It abounds in large and small canals, similar in appearance to the in-current and ex-current canals of the recent sponge tribe, and spicula are frequently found imbedded in it. From all these circumstances, therefore, we may reasonably conclude, that these nodules are only detached specimens of the same species of sponge, which we find, under circumstances more favourable for their increase, uniting into vast masses, and forming the great chert-bed of the Portland oolite.

At the Whetstone excavations of Broad Hemberry and Punchey-down, I found the chert nodules numerously dispersed amid the greensand beds, and presenting very much the same external appearance as those of the Fovant and Shaftsbury greensands. Upon breaking a considerable number of them, a clouded, white appearance, very similar to that observed in the Portland chert, was frequently to be seen; and upon examining this by the aid of a leiberkuhn and a power of two hundred linear, I found the spongeous texture abundantly dispersed through the specimens, and differing but slightly from the tissue described as occurring in the greensand cherts from Lyme Regis.—*March* 1841.

grains of chalk from the centre of a *paramoudra*, where we might with the greatest degree of reason expect to have found a more than ordinary quantity of silex intermixed, yielded but four per cent. of matter insoluble in muriatic acid, and of this probably one or more per cent. of the weight was owing to the impurity of the acid employed. If the immediate cause of the attraction of the silex had been due only to the presence of the spicula, it is probable that the animal matter would have undergone decomposition with a much greater degree of rapidity than appears to have been the case, and that the spicula would have been disengaged and precipitated to the bottom of the cavity caused by the imbedment of the sponge. But if we consider the attractive principle to have been the animal substances present, it will readily account for all the horny parts of the sponge, with the enclosed extraneous bodies, having retained the positions which they occupied during life; as the immediate and progressive deposition of the silex would probably afford a greater degree of strength and support to the tissues than that abstracted by their decomposition, and thus the whole would be sustained in its pristine form. The silicified shells of the greensand of Blackdown confirm this view of the cause of silicification, for in these testacea there are no siliceous spicula to serve as nuclei; the carbonate of lime having been completely dissolved and carried off by percolation, while the remaining animal matter, it would appear, has influenced the deposit of a solid and compact mass of pure siliceous material, unmixed with sand and unimpregnated by the silicate of iron immediately surrounding it; and the ligamentous hinge of the bivalves is frequently replaced in the same manner as the other parts of the shell.

In the corals of the mountain-limestone, and in those of the Tisbury limestone also, the same attraction appears to have been exerted, as in both instances we find a considerable portion of the carbonate of lime has been removed and its place supplied by silex; and in neither case can we suppose the previous existence of siliceous matter as an attractive agent.

From the foregoing facts, therefore, it appears probable, that these abundant deposits of silex are in a great measure due to the presence of either animal or vegetable matter, and especially to the former.

Similar phænomena have taken place, but with a different material, in the London, Kimmeridge, and Oxford clays; the fossilizing substance in such cases being sulphuret of iron in the place of silex. In nearly all these animal and vegetable remains, the tissues are literally replaced by sulphuret of iron. In the numerous pyritical remains of stems of trees and of fruits in the London clay we find the cells and vessels often completely hollow; while the delicate tissues forming their walls have been replaced by bright, thin films of pyrites. In the animal remains in the same formation this attraction has been exerted in a very striking

manner, the whole of the cartilaginous parts being frequently replaced by pyrites; and in other cases, as the fossilized crabs, where the animal matter contained within the shell has exuded slowly from the body, we trace its influence upon the surrounding matrix which had been impregnated with it; for in all the masses of indurated clay containing such remains, the hardness increases in proportion as we approximate to the body of the animal. The same law is also very happily illustrated by the state in which we usually find the remains of *Belemnites* in the lias shale of the Yorkshire coast; the anterior portion of the Belemnite being generally free from pyritical remains, while the alveolus is enveloped by a mass of indurated clay, which is universally found to become harder and more pyritical as we cut down towards the body of the animal.

Numerous other cases might be cited to illustrate the importance of the presence of the animal matter in the formation of the fossil, and to prove that it is to this agent more than to the presence of the mineral substances in the original body, that we are indebted for the preservation of these interesting remains of the former inhabitants of the earth.

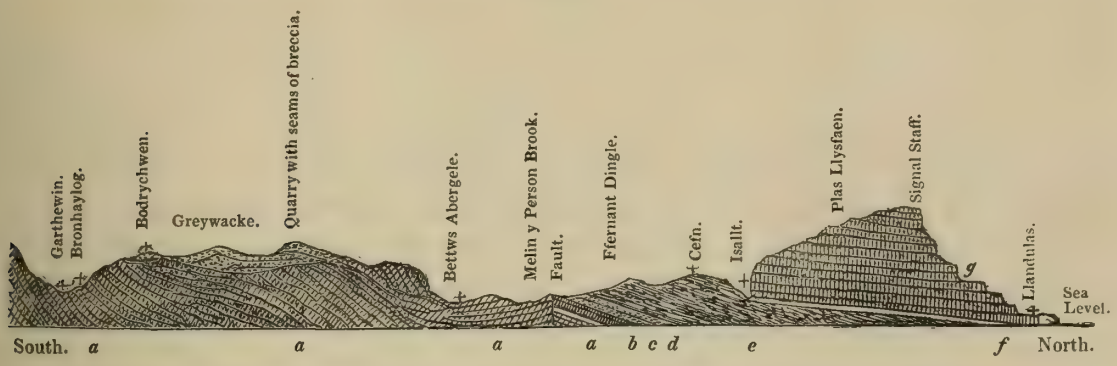
XVIII.—*Notes on a small Patch of Silurian Rocks to the West of Abergele, on the Northern Coast of Denbighshire; visited* 18*th and* 19*th July*, 1837.

By JOHN EDDOWES BOWMAN, Esq., F.L.S.

Communicated by R. I. MURCHISON, Esq., V.P.G.S.

[Read April 25, 1838.]

Section from Llandulas, three miles west of Abergele, on the north coast of Denbighshire, to Garthewin, distance nearly six miles.



a Blue slate, with shells and Encrinites.
b Fine blue clay.
c Arenaceous limestone.
d Arenaceous red conglomerate.
e Red marl, with pebbles.
f Green micaceous sandstone.
g Carboniferous limestone.

My attention was first directed to this locality by Mr. John Price, of the New College, Bristol, who had discovered it during his temporary residence at Llysfaen. It lies immediately to the south of the narrow belt of carboniferous limestone which skirts the coast from the Great Orme's Head near Conway, as far as the Point of Air and the Estuary of the Dee eastwards; and a little to the west of the brook Dulas, which discharges itself into the sea at Llandulas, about three miles west of Abergele. The belt of limestone is not here above a mile broad, and the dip of its strata is N. or N.E. Its southern limit (and also a great transverse rent through which the Dulas passes) shows the bold mural precipices so characteristic of this formation. Near the base of the precipices at Craig y Forwyn are a seam of

impure coal about a foot thick, and a thinner layer of bituminous shale with carbonized impressions of fine branches of *Lepidodendron* (?) and a leaf-like *Poacites*. I found also a small head of a species of Encrinite. Immediately under the limestone, at the foot of these precipices, is a thin seam of rounded pebbles of a greenish, slightly micaceous sandstone, containing a few bivalves and joints of *Encrinites* imbedded in a light loamy earth, and resting upon a thin bed of the same greenish sandstone (see *f*, woodcut). This pebble bed was *in situ*, and I afterwards saw it *in situ* also, and under the limestone, in several places on the north side of the calcareous formation ascending from the shore of Llandrillo Bay to Colwyn on the Holyhead road, but in these places the pebbles were often six, eight, and even twelve inches in diameter. Proceeding south or a little west of south from Craig y Forwyn, in the line of the section, I came upon a thick stratum of red marl (*e*, woodcut), in which are imbedded very numerous angular and water-worn pebbles, both of red and blue sandstone, the red most abundant, and of a liver-colour, compact, and micaceous, and imbedding many species of bivalves, apparently like those in the Ludlow rock. This marl forms the soil to the head of, and a considerable way down, Ffernant dingle, through which a little rill runs from north to south, and has hollowed out the banks so as to show a very good section. These pebbles are likewise found in the neighbouring fields, often attaining the dimensions of large boulders; also on the top of the limestone precipices, and beyond them on the beach below. In following the rill down Ffernant dingle, this bed varies in its characters into a compact marl or soft rock, and to a marly conglomerate, and is sometimes variegated with greenish and yellowish specks, but it has a pretty uniform dip to the north, at a considerable angle. From the extent of surface it covers, it is probably of considerable thickness. Underneath, or perhaps what is more properly its lower portion, is a compact arenaceous conglomerate (*d*, woodcut), forming a hard rock, and containing pebbles of liver-coloured and green, micaceous, shelly sandstone, more or less rounded; in some places mostly of small size, but in others much larger and coarser. In an adjoining wall I saw several boulders of this conglomerate more compact, and some quartzose and even jaspery, strongly resembling the rock near the Menai bridge and also one near Caernarvon. Still following the rill, this conglomerate is found lower down, resting on thin beds of compact reddish limestone (*c*, woodcut), containing few organic remains, and some irregularly-shaped flattened nodules. Pieces of this limestone are imbedded in the arenaceous conglomerate, and in one of them I observed a broken *Euomphalus*. The limestone is often so arenaceous as to become a calcareous sandstone, and sometimes it is as smooth and compact as the rock called Flummery-stone, which I have seen at Llanymynech, and at Coed Marchan in the Vale of Clwyd.

Near the lower end of the dingle, and just above a level on the right or west

bank, where a trial for copper is now carrying on, this limestone rests on a bed of very fine blue loamy clay (*b*, woodcut), which in its turn rests upon a blue clay-slate (*a*). At this spot is the fault represented in the section.

On the north side of the fault the dip of the strata is a little east of north, and at an angle of about thirty degrees with the horizon, which is conformable with the general inclination of the limestone; but on the south side the dip is south-west, and at a much less angle. In the trial level, and also in the lower portion of the dingle southwards, nothing is seen but the hard blue clay-slate, fine-grained and slightly micaceous, and containing, in the planes of stratification, here and there, a layer of small shells and obscure marks of vertical cleavage, similar to that which I have found in a coarser and harder clay-slate in the quarries of Nantglyn and Cyffylliog on the high plateau between the rivers Clwyd and Conway, and fifteen to twenty miles south-east of the present locality. I saw here none of the cleavage lines, sometimes straight, sometimes curved, which I observed on the flagstones at the above quarries. These lines are merely superficial, and are only observed by their micaceous or nacreous lustre. The transverse striæ on the large Orthoceras are very seldom found in the coarse flags at Nantglyn; the medial longitudinal line is a depression; the specimens, which taper abruptly about the middle, are from two to eight inches long and two inches across at the broad end.

The rill in Ffernant dingle discharges itself into Melin y Person brook, which runs eastward into the Dulas. The red marly conglomerate is succeeded on the south by a light greyish brown alluvium with blue slate pebbles, forming the surface south from Melin y Person brook. I then entered upon the slate or schistose rocks, which rise above the pretty village of Bettws Abergele on the south, showing great contortions and a nearly perpendicular stratification (as distinguished from cleavage); but a little further south the beds are variously inclined, both as to angle and the direction of the dip, showing considerable disruptive forces, apparently operating at different periods. On the height, to the left or east of the road, is a very hard fine-grained greywacke rock, enclosing detached joints of small Crinoidea. It has a cleavage sometimes approaching to columnar, like that of many traps or green-stones, separating the mass into large triangular or wedge-shaped pieces. Still further south, in a quarry on the right, the greywacke again occurs, and, in addition to this cleavage, it shows a distinct parallel stratification with a considerable dip to the south-east. The beds are each three to four feet thick, and above or upon them rest four other thin seams of the same, each from nine inches to a foot thick, alternating with seams of breccia of about equal thickness. The paste of the breccia is the same greywacke just described, with minute encrinital joints and other organic remains; while the imbedded material is a dark glossy clay-slate, mostly in angular fragments, and without any fossils.

A little south of this quarry, on the road from Bettws Abergele to Garthewin and Llanfair Tallhaiarn, the blue clay-slate (not fissile) again occurs; and in the heaps cut away to form the road I found abundance of fragments of small *Encrinites*, spiral univalves, bivalves, etc. They seemed to lie in layers, and are much decomposed from exposure, the spaces they have occupied being coated with a dark brown dust. Going down to Garthewin, the stratification is thinner and better defined, the dip about forty degrees to the north, and the rock decomposes into long thin splinters, but I saw no fossils.

Garthewin surprises the stranger by the secluded beauty of its situation among wooded slopes and bright green pastures. In adjoining walls I observed the tapering fossil (*Orthoceras* ?), already noticed as seen at Nantglyn, etc. From Garthewin (my most southern point) I turned east to the little village of Llanfair Tallhaiarn, etc., then north to some levels where an adventure for lead-ore is now carrying on, called Bronhaylog Upper and Lower Levels. In heaps of the excavated blue slate I found, chiefly in layers, abundance of joints and broken stems of small *Encrinites* and minute shells and other fossils, in general exceedingly sharp and clear and quite free from oxidation. They had not lain many days on the surface. Among them I saw a few indistinct *Orthocera* like those found in the blue slate of Ffernant dingle and near Bettws, Abergele, and at other localities.

List of Fossils determined by Mr. James de Carle Sowerby, F.L.S., with the geological positions assigned to the same species in the Silurian Series in Mr. Murchison's work.

Species 1 to 4 were obtained from the red and green sandstones, *e* and *f* of section, p. 195; and the remainder from the blue clay-slate, *a*.

1. Terebratula nucula	Silurian System.	Pl. V. f. 20.	Old Red.	Upper Ludlow.	Aymestry Limest.	Lower Ludlow.	
2. ——— pulchra ...	Ibid.	—— f. 21.	.....	Ibid.			
3. ——— navicula ...	Ibid.	—— f. 17.	.....	Ibid.	Ibid.		
4. Leptæna lata	Ibid.	Pl. III. f. 10 *b*. Pl. V. f. 13.	Ibid.	Ibid.	Ibid.		
5. Atrypa affinis	Ibid.	Pl. VI. f. 5.	.....	Ibid.	Ibid.	Ibid.	to Caradoc Sandstone.
6. Orthis lunata ?.....	Ibid.	Pl. III. f. 12. Pl. V. f. 15.	Ibid.	Ibid.	Ibid.	Ibid.	
7. ——— orbicularis.....	Ibid.	—— f. 16.	.....	Ibid.			
8. Lingula ?							
9. Avicula retroflexa	Ibid.	—— f. 9.	.....	Ibid.	.....	Ibid.	
10. Nucula ovalis	Ibid.	—— f. 8.	.....	Ibid.			
11. Cypricardia cymbæformis, *var.*	Ibid.	—— f. 6.	.....	Ibid.			
12. Orthoceras striatum	Ibid.	—— f. 29.	Ibid.	Ibid.	.....	Ibid.	
13. ——— annulatum ?	Ibid.	Pl. IX. f. 5.	.....	.....	.....	Ibid.	to Caradoc Sandstone.
14. ———inequiseptum?	Phillips's Geol. Yorks.	Pl. XXI. f. 7.	Mountn. Limestn.				
15. Bellerophon trilobatus...	Silurian System.	Pl. III. f. 16.	Old Red.				
16. Pleurotoma Lhudii?.....	Ibid.	Pl. VIII. f. 14.	.....	.....	.....	Ibid.	
17. Turbo corallii	Ibid.	Pl. V. f. 27.	.....	Ibid.	Ibid.		
18. Turritella							
19. Euomphalus funatus ...	Ibid.	Pl. XII. f. 20.	.....	Ibid.	Ibid.	Ibid.	to Caradoc Sandstone.
20. Trilobites							
21. Crinoidal stems							
22. Conularia quadrisulcata	Ibid.	—— f. 22.	.....	.....	.....	.....	Wenlock Limestone.

XIX.—*A Description of some of the Soft Parts, with the Integument, of the Hind-fin of the* Ichthyosaurus, *indicating the Shape of the Fin when recent.*

By RICHARD OWEN, Esq., F.R.S., F.G.S., etc.

[Read December 4, 1839.]

PLATE XX.

HITHERTO the exact shape and the nature of the soft parts of the paddles of the *Ichthyosaurus* have been matters of conjecture; the bony framework of these locomotive organs has alone been the subject of direct observation. But this part of the skeleton presents a striking deviation from the Reptilian and Mammalian types, inasmuch as in all existing air-breathing Vertebrates the number of digits of a locomotive member never exceeds five; while in the fore-fins of the *Ichthyosaurus communis* they are at least seven, of which some are bifurcated, and all consist of an extraordinary number of phalanges*. And, therefore, notwithstanding that the shape of these digital ossicles, their breadth and flatness and their large size, as compared with the joints of the fin-rays of Fishes, clearly indicate that the paddles of the *Ichthyosaurus* were enveloped in a smooth integument, the inference that the integument, as in the paddles of the Turtle and Porpoise, had no other support than was afforded by the bones and ligaments within, is less conclusive; and any direct evidence of the nature of the more perishable parts of the fin of the Ichthyosaur becomes peculiarly acceptable, when we attach due weight to the approximation to the Ichthyic structure made by the more enduring parts.

Sir Philip Grey Egerton, while examining a collection of Ichthyosaurian remains in the possession of Mr. Lee, of Barrow-on-Soar, with the same happy penetration which has already brought to light some of the most obscure and interesting points in the structure of the vertebral column of the *Ichthyosaurus*, detected the traces

* There are upwards of two hundred phalangeal ossicles, besides the eight metacarpals, in the fore-fin of the *Ichthyosaurus communis*.

of the soft parts of the fin in the slab of lias containing the mutilated paddle of the *Ichthyosaurus* here described.

It appears to be the posterior fin of the *Ich. communis*; the impressions and fractured portions of the two middle series of phalangeal ossicles are nearly complete, and there are the terminal portions of the two outer rows, making six digits in all. The impression, and a thin layer of the dark, carbonized integument of the terminal half of the fin, are most distinctly preserved and exposed on the fractured surface of the lias matrix. The contour of the extremity of the fin is thus clearly defined; and is accurately represented in the subjoined figure, Pl. XX. The anterior margin is formed by a smooth, unbroken, well-defined line, and appears to have been merely a duplicature of the integument; but the whole of the posterior margin exhibits the remains and impressions of a series of rays by which the fold of integument has been supported. Immediately posterior to the digital ossicles there is a band of carbonaceous matter varying from two to four lines in breadth, and extending in an obtuse, pointed form for an inch and a half beyond the digital ossicles; this I take to be the remains of the dense ligamentous matter which immediately invested the bones of the paddle; its fibrous structure is distinctly displayed. The rays, above mentioned, are continued from the posterior edge of this carbonized ligamentous matter, in which their bases appear to have been implanted: they extend, with a slight curve, obliquely downwards to the edge of the tegumentary impression; the upper rays are directed more transversely, but they gradually lie more in the direction of the axis of the fin as they approach its termination; the most interesting feature in these rays is, that they bifurcate as they approach the edge of the fin, the two branches diverging in a very slight degree, and thus repeating, as it were, the character of the digits themselves. From the rarity of their preservation, and their appearance and co-existence in the present instance with remains of the integument, it is evident that they were not osseous, but probably either cartilaginous or of that albuminous horn-like tissue of which the marginal rays consist in the fins of the Sharks and other Plagiostomous Fishes. Besides the impressions of the posterior marginal rays, there are others of not less interest in the present specimen: there is a series of raised transverse lines, crossing the whole of the fin at intervals of about one-eighth of an inch, having a very slight curve, with the concavity towards the end of the fin. As it is the inner surface of the integument which is exposed to view,—the opposite side of the paddle to that which is imbedded in the lias having, with portions of the digital ossicles, been broken away,—these fine transverse, raised lines probably indicate corresponding impressions on the exposed surface of the integument, and from their regularity I conclude that there was a division of the rigid integument into scutiform compartments analogous to those on the paddle of the Turtle and

webbed foot of the Crocodile, but differing in the absence of subdivision by secondary longitudinal impressions.

The known structure of the skeleton of the *Ichthyosaurus* admits of no doubt as to its being essentially an air-breathing, cold-blooded vertebrate animal, and consequently a reptile; the scutiform character of the integument covering the fin is therefore in harmony with the osseous structure. It might have been expected, *à priori*, that the skin, which, with its appendages, gives a character to the great primary groups of Vertebrata, and, as it were, reflects with more or less clearness their internal organization, should, in the extinct reptiles of the sea, exhibit some of the characters of the integument of existing reptiles *.

The other new facts which the present most interesting specimen has brought to light, equally accord with the indications of the natural affinities of the *Ichthyosauri* afforded by its more enduring remains. All the deviations from the Reptilian structure of the skeleton tend to the type of Fishes, and not to that of the *Cetaceous Mammalia*; this tendency has always been recognized in the well-known biconcave structure of the vertebræ; but in addition to this Ichthyic structure, the great number and the bifurcation of the digital bony rays of the fins, the great development of the cervical ribs, the enormous size of the intermaxillary bones, which support nearly the whole of the teeth of the upper jaw, the filling up of the cavities of the conical teeth by a coarse ossification of the remaining dental pulp, and the large size of the orbits and eyes,—all these particulars bespeak the close approach of the *Ichthyosauri* to the class of Fishes, and prepare us to receive with less surprise the evidence of a Malacopterygian structure of the fin afforded by the presence of a series of soft bifurcate rays in the posterior fold of the natatory integument.

* Evidences of the structure of the integument of the *Ichthyosaurus* have not escaped the observation of Dr. Buckland, who has particularly described it in a portion which corresponded with the interspaces of the sterno-costal bones, preserved, as in the present instance, in a specimen from the lias of Barrow-on-Soar. As might have been expected, the scutiform structure is not exhibited in the integuments covering the under surface of the body, but the epidermis here exhibits a fine wrinkled structure.—See *Bridgewater Treatise*, vol. ii. p. 22.

XX.—*Description of the Fossil Remains of a Mammal* (Hyracotherium leporinum) *and of a Bird* (Lithornis vulturinus) *from the London Clay.*

By RICHARD OWEN, Esq., F.R.S., F.G.S., etc.

[Read December 18, 1839.]

PLATE XXI.

UNTIL the present year, the remains of the highest organized animals which were known to exist in the marine Eocene deposit called the London Clay, were those of Reptiles and Fishes; and the danger of founding conclusions in Palæontology from negative evidence was, perhaps, never more strikingly illustrated than by the fact, that the first scientifically determined relic of a warm-blooded animal from that formation proved to belong not only to the Mammiferous class, but to the highest order of that class, if Man be excepted. Besides the remains of the Quadrumanous species just alluded to, there have since been discovered the teeth of *Cheiroptera*, of *Plantigrade* and *Digitigrade Carnivora*, and of a species probably belonging to the Marsupial order*. These most interesting fossils have been disinterred from the London clay, underlying the coralline crag, near Kyson in Suffolk.

I now propose to describe a fossil indicative of a new and extinct genus of the Pachydermal order, and the remains of a bird, both from the London clay at the estuary of the Thames; the latter fossils being the first of their class which have been discovered in this member of the Eocene tertiary deposits.

The Pachydermal fossil consists of a small mutilated cranium, about the size of that of a Hare, containing the molar teeth of the upper jaw nearly perfect and the sockets of the canines.

It was discovered in the cliffs of Studd Hill, about a mile to the west of Herne Bay, and was submitted to my examination by William Richardson, Esq., by whom it has since been presented to the Museum of the Royal College of Surgeons.†

* Annals of Natural History, Nov. 1839.

† For an account of the discovery of the *Hyracotherium* and a description of the beds near Herne Bay, see Mr. Richardson's paper, *postea*, p. 211.

The molars are seven in number on each side, and resemble more nearly those of the *Chæropotamus* than the molars of any other known *genus* of existing or extinct Mammalia. They consist of four spurious molars (*premolares*) and three true molars (*molares*), Pl. XXI.

The first and second spurious molars, counting from before backwards, have simple subcompressed crowns, surmounted by a single median conical cusp with a small anterior and posterior tubercle at the outer side, and a ridge along the inner side of its base: they are separated from each other by an interspace nearly equal to the antero-posterior diameter of the first molar, which measures two lines and a half. The second and the remaining molars are in close juxtaposition. The third and fourth false molars present a sudden increase of size and of complexity of the grinding surface, with a corresponding change of form. The plane or transverse section of the crown is subtriangular with the base outwards and nearly straight, the apex inwards and a little forwards, rounded off, to which the anterior and posterior sides converge in curved lines; the grinding surface supports three principal tubercles or cusps, two on the outer and one on the inner side: there are two smaller elevations, with a depression on the summit of each, situated in the middle of the crown, and the whole is surrounded with a ridge, which is developed into a small cusp at the anterior and external angle of the tooth. These teeth form the principal difference between the dentition of the present genus and that of the *Chæropotamus*, in which the corresponding false molars are relatively smaller and of a simpler construction, having only a single external pyramidal cusp, with an internal transverse ridge or talon at its base. The true molars, three in number on each side, closely correspond in structure with those of the *Chæropotamus*. They present four principal conical tubercles, situated at near the four angles of the quadrilateral grinding surface. Each transverse pair of tubercles is connected at the anterior part of their base by a ridge, which is raised midway into a smaller conical tubercle with an excavated apex. The crown of the tooth is surrounded by a well-marked ridge, which is developed, as in the third and fourth false molars, into a sharp-pointed cusp at the anterior and external angle of the tooth. The hindmost molar is more contracted posteriorly, and its quadrilateral figure less regular than the two preceding molars.

The sockets of the canines or tusks indicate that these teeth were relatively as large as in the Peccari; and that they were directed downwards as in that species, and as most probably also in the *Chæropotamus*. The temporal muscles were as well-developed as in the Peccari, the depressed surface for their attachment extending on each side of the cranium as far as the sagittal suture.

The frontal bones are divided by a continuation of the sagittal suture. The na-

sal suture runs transversely across the cranium parallel with the anterior boundary of the orbits.

The lacrymal bone reaches a very little way upon the face. The external angle of the base of the nasal bone, which is of considerable breadth, joins the lacrymal, and separates the superior maxillary from the frontal bone.

The anterior margin of the malar bone encroaches a little way upon the face at the anterior boundary of the orbit.

The external aperture of the sub-orbital canal is situated about three-fourths of an inch from the anterior boundary of the orbit.

The under surface of the palatal processes of the maxillary bones is rugose, as in the Peccari; the portion of the skull, including the intermaxillary bones and the incisive teeth, is unluckily broken off and lost.

That the eye was full and large, is indicated by the size of the optic foramen and the capacity of the orbit, the vertical diameter of which equals one inch.

The upper part of the cranium, anterior to the sagittal suture, is slightly convex from side to side, its longitudinal contour is nearly straight. The face gradually becomes narrower anteriorly; it is slightly concave at the sides.

The general form of the skull was probably intermediate in character between that of the Hog and the *Hyrax*. The large size of the eye must have given to the physiognomy of the living animal a resemblance to that of the Hare and other timid Rodentia.

Without intending to imply that the present small extinct Pachyderm was more closely allied to the *Hyrax* than as being a member of the same order, and similar in size, I propose to call the new genus which it unquestionably indicates, *Hyracotherium*, with the specific name *leporinum*.

The indications which the present fossil has yielded of the generic characters and form of the *Hyracotherium* are the more interesting on account of the absence of similar information regarding the equally rare extinct Eocene genus *Chæropotamus*, with which it is most closely allied.

The resemblance of the molar division of the dental system in the *Hyracotherium* and *Chæropotamus* is sufficiently close to warrant the conclusion, that their canines and incisors, if not precisely similar, would differ only in form and proportion. Hence we may venture to remove, analogically, some of the uncertainty which still attaches itself to the dental characters of the *Chæropotamus*.

"Avoit il en haut une canine comme en bas?" asks Cuvier, in his account of the fragments of jaws on which he founded the genus. Their presence in the present fossil warrants an affirmative reply being given to this question. With respect to the incisor teeth, these, together with the *ossa intermaxillaria*, are wanting in the present specimen; and they have not yet been found in any of the fragments

of the extremely rare Pachydermal genus *Chæropotamus*, to which the *Hyracotherium* bears the closest affinity.

Pl. XXI. Fig. 1 to 4.

Fig. 1. View of the palatal surface of the skull and of the grinding surface of the molar teeth of the *Hyracotherium leporinum*, natural size.

Fig. 2. View of the upper or coronal surface of the same.

Fig. 3. Side view of the same.

Fig. 4. The series of molar teeth, with the socket of the canine of the right side of the upper jaw, magnified two diameters.

Ornitholite. (Lithornis vulturinus, Pl. XXI. Fig. 5 and 6.)

The evidence of the coexistence of Birds with Mammals in the English Eocene tertiary formations rests upon two Ornitholites, including the most characteristic parts of the skeleton of a bird, viz. the sternum and sacrum; both these fossils are from the London clay at Sheppey. The first forms part of the extensive collection of organic remains which the celebrated John Hunter left at his decease, and I have availed myself of the permission granted me by the Museum Committee of the Royal College of Surgeons to describe it in connexion with the Mammalian fossil from the same formation already adduced in the present paper.

The second Ornitholite, consisting of the sacrum and part of the coccyx, is from the museum of Mr. Bowerbank, which is well known to be peculiarly rich in Sheppey fossils.

The Hunterian fossil (Fig. 5, 6.) includes the sternum nearly entire, the proximal ends of the coracoid bones, a dorsal vertebra, the distal end of the left femur, the proximal end of the corresponding tibia, and a few less characteristic fragments of ribs; all these bones are cemented together by the grey indurated clay which is generally more or less attached to the Sheppey fossils. A single glance at this characteristic specimen is sufficient to assure the comparative anatomist of the class of animals to which it belongs. The next question that arises is, to which of the three great primary groups of Birds the fossil is to be referred? Whether to the aquatic, the terrestrial, or the aerial birds of the philosophical ornithologist, Nitzsch?

The length of the sternum and the remains of the primary intermuscular crest or keel forbid a reference of the fossil to the Struthious or strictly terrestrial order, but at the same time do not prove so decidedly, as might be supposed, that the fossil must have belonged to a bird of flight.

The Penguins and other Brachyptera, having need of muscular forces to work the wings as paddles while making their way under water, almost equal to those

which propel the bird of flight through the air, possess a long sternum with a well-developed keel.

The coracoid bones or posterior clavicles are even less available in this question, as they relate much more closely to the respiratory actions than to the movements of the wings, and accordingly are always present and strongly developed, even in such birds as the *Apteryx*, in which the wings are reduced to their feeblest rudiments.

In the present fossil, however, the lateral extent and convexity of the sternal plate, the presence and course of the secondary intermuscular ridges, the commencement of the keel a little way behind the anterior margin of the sternum, all prove the fossil to have no affinity with the Brachypterous family.

There then remain for comparison the ordinary birds of flight, and of these our native species, which resemble the fossil in size, are the first to claim attention. It would have been by no means difficult to have assigned its natural family to the Eocene Bird, if we had possessed the sternum entire or with its characteristic posterior margin, but this part is unfortunately wanting in the fossil. Sufficient, however, of the bone remains to enable us to set aside the Gallinaceous and those Grallatorial and Passerine birds which have deeply incised sternums; and the field of comparison is thus restricted to such species as have the sternum either entire or with shallow posterior emarginations. Between the fossil and the corresponding part of the skeleton of such birds it became requisite to institute a close comparison in regard to many minor details and modifications, as, for example, the secondary muscular impressions and ridges on the flat surface of the sternum; its costal margin and anterior angle; the form and extent of the coracoid groove; the conformation of the sternal end of the coracoid bone, combined with the form and relative size of the preserved articular extremities of the femur and tibia.

It is unnecessary, however, to recount all the details of these comparisons; suffice it to say, that after pursuing them from the Sea-gull and other aquatic species upwards through the Grallatorial and Passerine orders, omitting few of the species and none of the genera of these orders to which belong British birds approaching or resembling the fossil in size, the greatest number of correspondences with the fossil were at length detected in the skeletons of the Accipitrine species.

The resemblance was not, however, sufficiently close to admit of the fossil being referred to any of the existing native genera of Raptorial birds. The breadth of the proximal end of the coracoid removed the fossil from the Owls (*Strigidæ*), and the shaft of the same bone was too slender for the *Falconidæ*; the femur and tibia were likewise relatively weaker than in most of our Hawks or Buzzards. It is with the skeletons of the Vultures that the fossil presents the closest agreement. In the

small Turkey-Vulture (*Cathartes aura*), for example, besides the same general form and proportions of the bones, so far as they exist in the fossil, we have the same degree of development, and the same direction of the intermuscular ridge on the under surface of the sternum, which divides the origins of the great and second pectoral muscles. The outer angle of the proximal end of the coracoid is produced in the same degree and form, and a similar intermuscular ridge is present on the anterior and towards the outer part of the coracoid. The preserved extremities of the femur and tibia have the same conformation and relative size in the fossil as in the existing *Cathartes*. In this genus, nevertheless, there is a deeper depression on the outer surface of the sternum, external to the coracoid groove, than in the fossil, but this difference is less marked in some of the larger *Vulturidæ*. The fossil, moreover, indicates a smaller species of Vulturine birds than is known to exist in the present day, and probably belonged to a distinct subgenus.

The professed ornithologist may receive with reasonable hesitation a determination of the family affinities of an Ornithic fossil arrived at in the absence of the usual characters afforded by the beak and feet; but the comparisons instituted in reference to the present fossil have established so many unexpected points of difference and resemblance, as to embolden me confidently to anticipate, in the event of the subsequent discovery of the cranium and mandibles, the bones of the extremities, or the entire sternum, that they will establish the conclusion that the Sheppey Ornitholite is referable to a member of the group of Accipitrine Scavengers which are so abundant in the warmer latitudes of the present world.

The Ornitholite in the museum of Mr. Bowerbank consists of ten sacral vertebræ anchylosed together, as is usual in Birds, with a continuous, keel-like, spinal ridge; four of these confluent vertebræ are analogous to the lumbar vertebræ in the Mammalia, and they are succeeded by five others, in which, as in the Vultures, the inferior transverse processes are not developed; this character is, however, by no means peculiar to the *Vulturidæ*. The part preserved in the fossil, though eminently characteristic of the class of birds, is not one which is calculated to throw light on the closer affinities of the species to which it belongs.

For the species of *Vulturidæ* indicated by the above-described fossils, the name of *Lithornis vulturinus* may be provisionally given.

Pl. XXI.

Fig. 5. Front view of the Hunterian Ornitholite.
Fig. 6. Side view of the same, of the natural size.

XXI.—*Description of some* Ophidiolites (Palæophis toliapicus) *from the London Clay at Sheppey, indicative of an extinct species of Serpent.*

By RICHARD OWEN, Esq., F.R.S., F.G.S.

PLATE XXII.

WHILST recording the evidences of the warm-blooded Vertebrates which have been found in the London Clay, I take the opportunity of describing some fossils from the same formation, referable to an order of reptiles which appears to have been very sparingly represented in the fauna of former periods of the history of the earth.

Vertebræ joined enarthrodially by a deep anterior transversely oblong cup and a corresponding prominent posterior ball, and further articulated by two projecting posterior flat oblique processes wedged like the carpenter's tenon into a mortice excavated in the anterior oblique processes of the succeeding vertebra; supporting, moreover, on either side of the fore-part of the body, an oblong convexity for the moveable articulation of the rib, belong unequivocally to a reptile of the Ophidian order.

A group of about thirty vertebræ of this description, with a number of long and slender ribs, having expanded concave vertebral extremities, cemented irregularly together by a mass of indurated clay, forms part of the choice collection of fossils left by John Hunter, and now in the Museum of the Royal College of Surgeons, London*.

A portion of the spinal column of apparently the same species of Serpent, measuring eighteen inches in length, and including twenty-eight vertebræ; a smaller group of seven vertebræ, and a few detached ones, are contained in the museum of Mr. Bowerbank.

All these specimens are from the Isle of Sheppey.

The vertebræ in each specimen present the same conformation and nearly the same size: they are as large as those of a Boa Constrictor ten feet in length. They belong to the ordinary dorsal or costal series, but differ from the vertebræ of both *Boa* and *Python* in their superior length, as compared with their breadth and

* This specimen is here described and figured by permission of the Museum Committee of the Royal College of Surgeons.

height. The ridge continued from the lower anterior to the lower posterior oblique processes on each side is less developed in the fossil Ophidian. The oblique processes themselves do not extend so far outwards; and the spinous process is narrower in its antero-posterior extent, but longer.

In the first two of the above-mentioned differences the fossil agrees with the Linnæan genus *Coluber* and its subgenera, but differs from the *Crotalus*; in the remaining points it differs from *Crotalus*, *Coluber*, *Najia*, and *Trigonocephalus*. The long and comparatively narrow spine, the outward and backward prolongation of the upper angle of the posterior oblique processes, the uniform convexity of the costal protuberance, the uneven or finely-wrinkled external surface of the superior arch of the vertebra, are characters which distinguish the present Ophidian vertebræ from those of any other genus of the order with which I have been able to compare them; and I therefore propose to designate the species provisionally by the name of *Palæophis toliapicus*.

The ribs, as in all land-serpents, are hollow.

In some respects, as the configuration of the under surface of the body of the vertebræ and in the anterior tubercle upon this surface, the fossils agree with the *Boæ* and *Pythons* more nearly than with the *Colubri*, in which the under surface of the abdominal vertebræ are traversed by a median longitudinal ridge; and in none of the differences above noted can there be inferred any obstacle to the practice of the same arts of entrapping and modes of destroying a living and struggling prey.

The largest of these Ophidiolites in Mr. Bowerbank's collection exhibits a portion of the vertebral column suddenly bent upon itself, and indicating the usual lateral flexibility of the spine.

If we may suppose the species to have had the same number of vertebræ as the existing Boas, it must have exceeded eleven feet in length, and such dimensions would indicate that the species was not provided with poison-fangs. Serpents, of these dimensions, exist in the present day only in warm or tropical regions, and their food is by no means restricted to animals of the cold-blooded classes. The remains of Birds and Mammalia are those which are most commonly found in the alimentary canal of such as are brought to this country dead; and living birds or quadrupeds also constitute the favourite food of the Pythons and Boas, of similar dimensions, which are exhibited in our menageries. If, therefore, there had not been obtained direct evidence of both Birds and Mammals in the London clay, I should have felt persuaded that they must have coexisted with Serpents of such dimensions as the species of which the dorsal vertebræ and ribs are here described.

XXII.—*Observations on the Locality of the* Hyracotherium.

By WILLIAM RICHARDSON, Esq., M.A., F.G.S.

[Read December 18th, 1839.]

IN the year 1829, when I first became acquainted with that portion of the London clay formation which extends on the northern coast of Kent from Whitstable to Herne Bay, it presented, with exceptions too unimportant for notice, one uniform lithological aspect. The cliffs or escarpments on this line of coast, proceeding from Herne Bay westward, are Hampton Cliff, Studd Hill, Swale Cliff, or rather cliffs, for there are many, and Tankerton Cliff. Hampton Cliff attains an elevation of 100 feet, Studd Hill of fifty feet, and the Swale Cliffs average a similar altitude; while Tankerton Cliff, with its undulating outline, terminating at Whitstable, is about sixty feet in height. These several cliffs, in the year 1829, could be at once identified as members of the London clay, as well by their mineral aspect as by their organic contents. They were capped with vegetable mould to the extent of one or two feet; beneath which were three or four feet of yellow marl or brick earth, containing rolled and angular flints, numerous mammalian remains, and fossils derived from secondary strata. The flints and fossils were confined to the upper portion of this bed, and the marl to the lower. To this marl succeeded, in the descending order, the London clay, consisting of a dark brown incoherent rock, abounding in septaria, selenite and wood, completely pyritized. The fossil contents of the clay were also similar, or nearly so, in these several cliffs, consisting of the teeth and vertebræ of fish, nautili, and other marine testacea characteristic of the London clay, encrinal and pentacrinal stems, and the usual crustaceous remains. In none, however, did I ever discover a solitary fragment of the reptiles which have rendered the neighbouring cliffs of Sheppey so celebrated. At the period of which I am writing, 1829, with the exception of slender fragments of the trunks and branches of trees, fossils of the vegetable kingdom were rare.

Such was the condition, lithological and fossil, of these cliffs in the year 1829, and such, with the exception of Studd Hill, are the characters which for the most

part still prevail. If there be variations in the conditions of Hampton Cliff, Swale Cliff, and Tankerton Cliff, they consist in the quantity and not in the characters of the mineral and organic contents.

The whole of this line of coast is exposed to rapid degradation, from the encroachment of the sea, and from the influence of land-springs, the former undermining the cliffs at their base, the latter loosening and ultimately detaching, in the form of land-slips, the upper portions. So rapid and extensive is the destruction thus effected, that in the spring of each year, when the agents of violence are in their greatest activity, many acres of ground are removed in a single week, and the whole physical outline of the coast is so altered, that the visitor of the previous summer can with difficulty recognize the scene with which, so recently, he was familiar.

With regard to Studd Hill, the facts disclosed by this unceasing progress of degradation are singular and interesting. The marine character, as respects the fossil contents, which, in common with the neighbouring cliffs on either side, it presented in the year 1829, has been gradually becoming less prominent, while the fluvio-marine nature of its organic remains has, as gradually, become more so. During my visit in the autumn of this year (1839), I could not procure from it a single marine shell; the septaria had nearly disappeared; no crustaceous remains were discovered; and the only organic products which lent to the deposit the most distant pretensions to a marine origin, were a few fragments of encrinal and pentacrinal stems; the dark brown incoherent clay had also been exchanged for a deep blue tenacious clay; selenite still abounded, and with it the source of its own existence, sulphuret of iron. The absence, however, of marine fossils has been abundantly supplied by a prodigious increase of terrestrial vegetable remains: I have collected and forwarded to Mr. James Bowerbank, who is publishing the Fossil Flora of the London clay, more than 500 fossil vegetable cones: fruits and other seed-vessels are as various and as abundant as those obtained from the Sheppey beds, and may be procured by the bushel; while the fragments of small trees or underwood, converted into pyrites, are so abundant, as to be removed for œconomical purposes by barge-loads: the collection and sale of the pyritical wood is a source of considerable profit to the neighbouring peasantry. The condition in which these vegetable remains are found, precludes the supposition of their having been much, if at all, drifted, the rounded and worn appearance of many resulting from the action of the tide and shingle upon them, after they have been detached from the cliff; those which are secured at the moment of their fall, preserve the smallest fibres uninjured.

No land or freshwater shells have been observed.

Struck by the fact of this total change in the character of the organic contents of Studd Hill, and notwithstanding the then unprecedented fact of mammalian

remains occurring in the Eocene period of the tertiary formations, I looked with strong expectation for the evidence of some form of animal life, whether of beast or bird, destined to be sustained by so rich a provision. I was justified in this expectation by the knowledge that nature ever directs her means, as well in number as in fitness, to particular ends. My search was, however, fruitless until the month of September last, when, continuing my pursuit, I was fortunate enough to find the cranium of the *Hyracotherium* *.

The discovery of this Mammal, and the contemporaneous announcement of other mammalian remains having been obtained by Mr. Colchester from certain sand-beds at Kison near Woodbridge, and which strata are supposed to constitute a portion of the London-clay formation of that district, are facts of great geological interest. But whether the Eocene character of the Kison beds be ultimately established or not, the Eocene character of the *Hyracotherium* locality is placed beyond the reach of doubt. Independent of the intrinsic evidence of the locality itself, the associated fossils, identical with those of the neighbouring Sheppey beds, establishes the fact; the Sheppey beds themselves may be traced without a break to Studd Hill, and, with the exception of the superimposed diluvial gravel, there is neither above nor below the London clay at Studd Hill any portion of any other formation.

The discovery of Mammifers in the London clay affords another instance of the fallacy of resting conclusions in natural science on negative evidence, which is, in fact, no evidence at all.

[*Note.*

In a former paper on the coast-section from Whitstable in Kent to the North Foreland, and read April 9th, 1834, Mr. Richardson described the changes which this part of the coast of Kent had undergone. He stated that the point still called the Old Haven to the eastward of Herne Bay, retains not a single feature to justify the appellation. The dimensions of the Haven were, however, at one time sufficient to afford protection to fishing-vessels of sixty tons burthen, though it is now unable to shelter a custom-house galley drawing one foot of water. With respect to Herne Bay, tradition preserves the memory of an upper and a lower bay; and the inhabitants residing to the westward of the new pier, erected on a shallow, where the horn which separated the two bays projected, are said to live in the upper bay; but scarcely a vestige of either bay remains. In the same paper the author gave a detailed account of the structure of the London clay cliffs, a condensed notice of which is given by him in the above memoir on the locality of the *Hyra-*

* See Mr. Owen's description of the cranium of the *Hyracotherium*, *ante*, p. 203, *et seq.*

cotherium; but as his previous account of the plastic clay series is not alluded to by him in this communication, it has been thought advisable to give the following abridgement. Only the sandy beds of the formation occur on this part of the coast. They first appear from under the London clay about three quarters of a mile eastward of Herne Bay, and continue to rise in an unbroken line until they attain the altitude of 100 feet at the Old Haven, whence they irregularly decline to a very low cliff, over which the sea breaks at exceedingly high tides, about one furlong west of the Reculver towers. From this point they again rise to the height of sixty feet under the towers, where the sands terminate abruptly as a cliff, forming only low land and marshes to the rise of the chalk near Birchington.

The following sections are given of the beds near Bishopstone, and those which constitute the cliff on which are situated the Reculver towers.

Bishopstone:

Vegetable soil	2 feet.	Compact sandstone, at intervals	6 feet.
Calcareous loam, with flints	3 —	Brown sand	15 —
Yellow sand	10 —	Second shelly bed	1½ —
Shelly bed	1 —	Dark yellow sand	15 —
Yellow sand	12 —	Brown sand	12 —
Pebble bed	2 —		89½
White sand, occasionally ferruginous	10 —		

Minute particles of broken shells occur throughout the section.

Reculver Towers:

Vegetable soil and decayed human remains	8 feet.
Yellow sand	10 —
Brown sand	12 —
Imperfect shell bed	0½ —
Brown sand	12 —
	38½

Teeth and other remains of fishes are found in the sands of the formation; also testacea, though generally too decomposed to be preserved for examination, but the author found a *Trochus*, a *Cerithium*, and a *Venus*. Iron pyrites are sparingly dispersed through the strata; and a few dark lines indicate the existence of carbonaceous matter.

The chalk rises from beneath the plastic sands at an angle of five or six degrees; but the upper or flinty chalk is stated to have been removed throughout nearly the whole district from Birchington to Margate, the debris resulting from its destruction being spread over the hills as well as in the valleys.—Editor.]

XXIII.—*On the Great Fault called the Horse in the Forest of Dean Coal-Field.*

By JOHN BUDDLE, Esq., F.G.S.

[Read April 8th, 1840.]

THE great fault in the Forest of Dean, called "the Horse," ranges in the direction of S. 31° E. by compass, in the Coleford High Delf seam of coal.

The term Fault is used here in conformity with the usual mining phraseology, which assigns that term to any interruption in the regular deposition of the seam, or *vein* of coal. The Horse, however, is not what geologists term a *fault*, as there is no accompanying dislocation of the strata. The coal is deteriorated in quality in some places, in others it is considerably thinner than the average height of the seam or *vein*, and in the principal part of the Horse it is altogether wanting. (See accompanying Section, woodcut, fig. 1.)

It may also be observed, that the miners in Dean Forest apply the term vein to a stratum of coal, while this term in the north of England is applied to mineral veins only; and many similar instances exist in mining districts where local terms convey an erroneous impression, either as compared with the terms used in other places or with the scientific language of Geology.

That portion more particularly called the Horse has been traced by the workings on each side of it in Coleford High Delf seam about two miles, and its breadth varies as shown on the accompanying plan, from 170 to 340 yards. (See woodcut, fig. 2.) The only drift or tunnel which has been carried through it, in a transverse direction, passes under Barn Hill enclosure, between Bixslade and Howler's-slade valleys, where its width is about 200 yards. (Woodcut, fig. 1.)

It will be seen by the accompanying Section (fig. 1.), that the upper part of

the seam of coal, to a considerable distance on both sides of it, undulates and is irregular, causing the seam to vary in thickness, while the pavement nearly preserves its ordinary regularity. The depressions of the roof, as shown in the Section, are called "Lows" by the colliers.

The pavement is composed of the ordinary argillaceous deposit which accompanies the seam all through the Forest Basin, and the roof is formed of the strong sandstone which usually reposes upon the Coleford High Delf seam, with the occasional interposition between it and the coal of a thin layer of a black slaty substance.

The coal under the depressions of the roof or lows is generally deteriorated in quality by being intermingled with particles of the sandstone of the roof; but it is not mixed with boulders, angular fragments, and gravel, as has been erroneously imagined. What have been understood to be boulders and gravel are nodules of highly indurated, ferruginous sandstone of various sizes, some very large, scattered irregularly through the thick stratum of sandstone, forming the roof of the Coleford High Delf seam. These nodules are generally of a spherical form, but some of them are kidney-shaped, and others are only sections or parts of spheres. The latter cannot be detached from the surrounding sandstone rock, but form part of it, and generally occur in the middle of the "pannels" of the rock, in the solid part between the beds and partings or backs.

The more perfectly formed nodules, called *Yolks* by the miners, lie in a mould formed in the rock to which they are attached by their ferruginous coating, but the surrounding and immediately adjoining parts of the stone are much indurated, and radiating cracks generally proceed from the sides of the cavities. These yolks occur in all parts, sometimes in the middle of the pannels and sometimes near the joints.

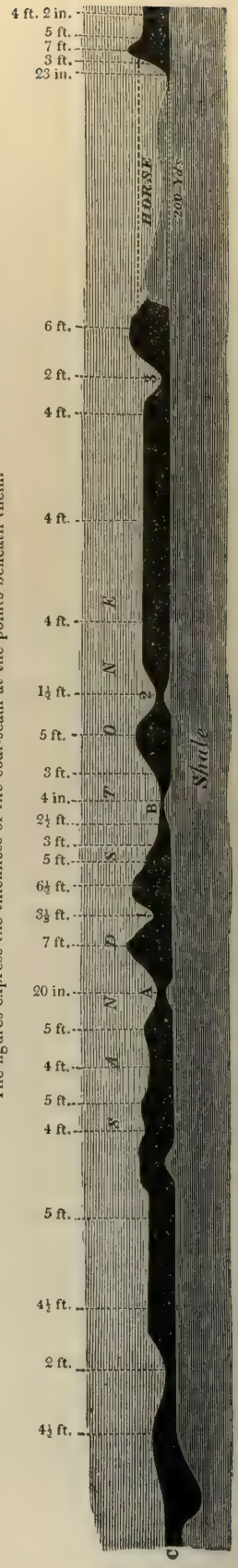


Fig. 1.—Cross Section of the Horse Fault as passed through by the Drift C D of the Plan.

The figures express the thickness of the coal-seam at the points beneath them.

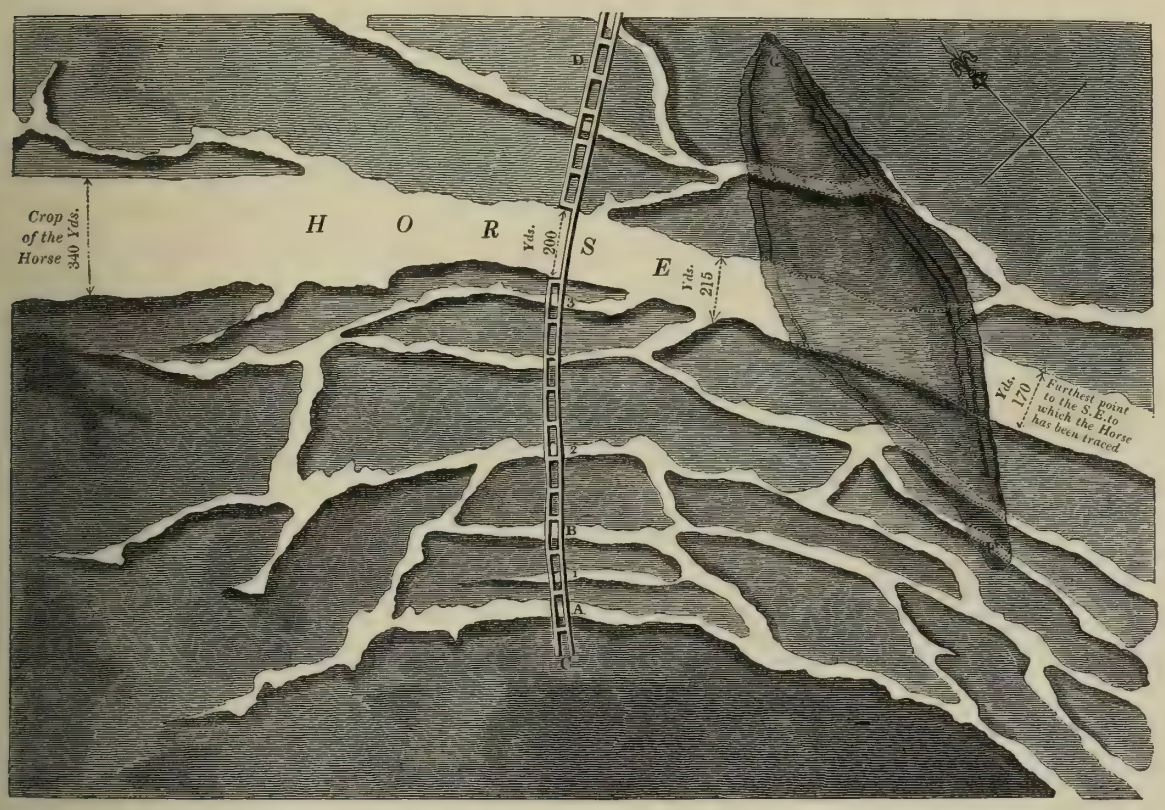
The angular fragments found scattered in the sandstone roof of the coal are obliterated or imperfect casts of vegetable remains. They are of the same sort of sandstone as that which surrounds them, but highly indurated, as is also the adjoining part of the rock to some distance; but they have not the ferruginous appearance of the nodules, although they are equally as hard.

It is reported that similar nodules are found in the sandstone rock between the Coleford High Delf and the Trenchard coal, which lies about sixty yards below.

The sandstone which forms the roof of the coal extends to the surface and varies in thickness according to the undulations of the ground: at the part where the cross-section of the Horse is given, it is about ninety-four yards in the thickest part.

Fig. 2.

Plan of the Horse Fault, with its collateral branches called Lows. (Scale 24 chains to an inch.)



Some portions of the roof in the Horse and Lows consist of a sandstone breccia, containing quartz pebbles similar to those which abound in the pudding-stone of the forest, also fragments of coal, ironstone, and vegetable remains. The pudding-stone of the Forest Basin lies between the carboniferous limestone and the old red sandstone, and it crops out all around the basin, attaining a considerable elevation in the adjoining hills.

The Coleford High Delf is the only seam of coal in which the Horse is clearly developed; it is the twenty-third seam in the Dean Forest series in the descending order, and the third from the lowest.

Whether the Horse may produce any change in the seams lying above the Coleford High Delf, can be ascertained only by the future working of those seams; but from the regular and uniform nature of the pavement, and from the entire absence of sandstone in it, there is no reason to think that the Horse goes any lower down than the seam.

On considering the various phænomena presented by this fault, and the seam of coal on each side of it, we may infer that it occupies the site of a lake which existed at the period of the deposition of the High Delf seam; and that the carbonaceous matter which formed the seam was accumulated while the water was deep and tranquil.

The undulations in the top of the coal on each side of the Horse, it may be presumed, were occasioned by abrasion, when the water was discharged from the lake; and that the Horse itself occupies the bed of the river, by which the complete drainage of the lake was effected, and which washed the coal entirely out.

This is the more probable, as those undulations or *lows* appear to have been formed by smaller collateral streams and rills of water. Two of the largest, marked A and B, fig. 2, have been traced to a considerable extent, as shown on the Plan. The other Lows have been found in the workings on each side of the drift C, D, which is on the line of the section.

The sandstone roof of the coal and the filling up of the rills which form the lows, and which are a part of the roof-stone, have been formed by subsequent deposition, and become consolidated by pressure.

The roof is a fine, close, granular sandstone, without ripple marks, containing only a few ill-defined vegetable remains, and has every appearance of tranquil deposition.

The fall of the Horse is conformable with that of the strata, viz. S. 31° E., as far as it has been traced, and at the same rate; but whether it may continue this conformity, and rise with the seam of coal, to its outcrop, on the S.E. side of the Forest Basin, has not yet been ascertained. The bed of the Horse on its transverse section is nearly horizontal.

There is no indication on the surface by which the Horse can be traced, beyond the limit to which it has been explored in the pits.

In its underground character this fault is similar to those *washes* or aqueous deposits in many coal districts, but it differs from them in not being under the bed of any river, nor in the bottom of a valley, nor does it show itself at the surface.

In the Newcastle coal-field, all the *washes* which have been met with cut through the whole of the strata, from the surface to that on which they repose.

Should subsequent workings prove that the Horse does not extend through the upper seams, it will be evident that the river of which the Horse had been the bed did not cut through the superincumbent strata, but that its period of action was antecedent to their deposition.

In the workings of the Park End Colliery, in Park End High Delf seam, which is the thirteenth in the series, and lies about fifty fathoms above the Coleford High Delf, a great succession of *lows* has been met with in crossing the line of the Horse, and similar to those on each side of it, but no "Fault" corresponding with the Horse itself has been discovered. (See fig. 3.)

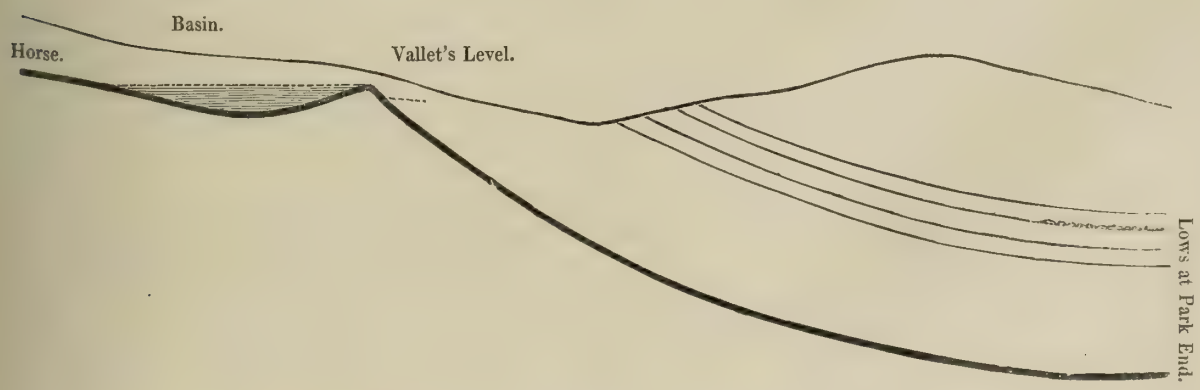
The part of the Forest Basin where those irregularities occur is two miles further to the S.E. than the point to which the Horse has been traced in the Coleford High Delf in Vallet's Level. But whether those irregularities at Park End have any connexion with the Horse has not yet been ascertained. The workings at Park End are on the S.E. side of the Basin beyond its centre, where the strata rise in the opposite direction from the point to which the Horse has been traced.

The full extent of the Horse in the Coleford High Delf seam, and whether it has affected any of the other seams, can only be ascertained by the future working of the coal.

The accompanying diagram (fig. 3.) shows the relative position of the Horse and the Lows at Park End.

About half a mile to the S.E. from the line of the section (see fig. 2. and fig. 3.), in the direction of the Horse, is an extraordinary depression of the Coleford High Delf seam of an oval shape, as represented by the tinted portion of the Plan, marked F G. The centre of this part is considered to be twenty feet deeper than the ordinary level of the seam round its margin; but the coal has not yet been worked in it. The fact, therefore, of the Horse presenting the same phænomena in this depression as it does on both sides of it, is yet to be proved, which will be done ere long by the works now in progress. The present workings only skirt the margin of this small basin, which has the appearance of having been a pool in the bottom of the lake thus:

Fig. 3.



In examining the upper seams at Park End Colliery, in the line of the Horse, there appears to have been some deteriorating cause, and it is a question whether the flowing of the river might not extend over some of those seams by virtue of their lower position as regards level.

There is a bare possibility that the subsidence of the Cannop Brook Valley, if it was prior to the deposition of the upper seams, might occasion such a want of conformity in the action of the river. At all events the deterioration of the upper seam at Park End being exactly in the line or direction of the Horse, is a circumstance which merits notice, and the investigation, if pursued, may probably throw much light on the history of the formation of this basin.

The question is, did the upper seams ever extend over the site of the Horse, or were they only deposited in the depression where they now are? Until it is ascertained whether the Horse follows the High Delf seam of coal only, it will be difficult to form an opinion on this question, but the mining operations of Mr. Mushet and others will shortly bring this to light.

XXIV.—*On the Distribution and Classification of the older or Palæozoic Deposits of the North of Germany and Belgium, and their comparison with Formations of the same age in the British Isles.*

By the Rev. ADAM SEDGWICK, F.R.S., F.G.S.,
Woodwardian Professor in the University of Cambridge;

And RODERICK IMPEY MURCHISON, Esq., F.R.S., F.G.S., &c.

(Followed by a Description of the Fossil Mollusca, by Viscount D'ARCHIAC and M. E. DE VERNEUIL, Members of the Geological Society of France, &c. &c.)

[Read May 13 and 27, 1840.]

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Introduction.

BEFORE we give to the Society the results of our examination of the older stratified rocks of the Rhenish provinces, the Hartz, and Franconia, it may be well to state, in a few words, the objects we had in view at the commencement of our labours in the early part of last summer. When we entered, during the summer of 1836, upon an examination of the structure of North Devon, our sole aim was to determine the position and relations of the culmiferous strata, about which there had been much controversy. Before our task could be completed, we were led to an examination of the lower groups of strata both in North and South Devon, and to follow them in their prolongation into Cornwall; and we at length arrived at the conclusion, that nearly all the older stratified rocks of both counties belonged to one epoch, and must be included under one common designation. We proposed the name of *Devonian system* for this great series of deposits, and we placed it in a position intermediate between the lower carboniferous and the upper Silurian groups; and therefore on the exact parallel of the old red sandstone, of which it was assumed to be the equivalent under a new mineral type*. We need not inform the Society that this classification was strenuously opposed at the time it was first brought forward, and that it has been combated in some public journals since the appearance of our abstracts; nor do we now deny that it was encumbered with great difficulties. To believe that a limestone (like that of South Devon)

* See Geol. Trans., vol. v. p. 633 *et seq.*

overlaid by many thousand feet of slate rocks almost devoid of fossils, was of the date of the old red sandstone, and that the greater part of the slates of Cornwall (heretofore regarded, from their crystalline structure, as primary formations of great antiquity) also belonged to the same epoch, required no common confidence in the weight of evidence offered by groups of fossils. With good hopes, but not without considerable anxiety, we therefore resolved to examine some of the continental localities which seemed likely to throw light on our proposed classification; conscious that it could never meet with general acceptance unless confirmed by some analogous development of the upper transition rocks of France and Germany.

We at first intended to commence our observations in Brittany, which, from its geographical position, might be expected to offer some analogies of structure with Devonshire and Cornwall. We however abandoned that intention on learning, from the geologists of France, that the connexion between the carboniferous system and the inferior strata was obscurely exhibited in that region, and that the evidence offered by the fossils of the lower groups was meagre and unsatisfactory. We therefore resolved to begin with the transition rocks of the Rhenish provinces, knowing that on both banks of the Rhine we should be conducted through a true carboniferous series, based on mountain limestone, into still lower groups of strata. If, therefore, in the examination of these regions, we could discover a series of beds mineralogically and zoologically intermediate between the carboniferous and Silurian systems, then would our proposed classification be confirmed by evidence of a higher nature than any offered by our English sections, none of which were perfect. But if, on the other hand, no such intermediate series were exhibited, then would our Devonian system be unsupported by that direct evidence of superposition which seems essential to its permanent acceptance as an European Deposit.

Of the Belgian groups we had some knowledge, chiefly from the descriptions of M. D'Omalius d'Halloy and Professor Dumont; and it appeared to us quite certain that the three lower members of the *système anthraxifère* (notwithstanding the more recent comparison of them with the *Silurian system*) must be exactly, or very nearly, the equivalents of a higher group of rocks, to which we had given the name *Devonian*. For the *système anthraxifère* was, as its name implied, anthraxiferous; its upper division was, from its fossils, the representative of our *mountain limestone*; and even in its lowest division there appeared (from the published lists) to be a few mountain limestone fossils: at the same time, we were unwilling, in the commencement of our labours, to encounter the peculiar difficulties of the Belgian sections.

The coal-field of Dortmund and the great chain of the supposed mountain limestone, extending (as represented in the maps of Von Buch and Hoffmann) from the right bank of the Rhine to the confines of Hessia, seemed to offer a more inviting

base-line; and we hoped to find on some part of it clear evidence of the true succession of the inferior groups. We approached this line, in the first instance, by a traverse from the neighbourhood of Frankfort; and by a long series of other traverses through Nassau and the adjacent tracts of country, we endeavoured to connect together the great formations which are spread out between Westphalia and the chain of the Taunus.

We afterwards crossed the plains of Hessia to the chain of the Hartz, portions of which we examined in some detail; and anxious (before our return to the provinces on the Rhine) to see a country which has become classical through the labours of Count Münster, we made one long traverse from the borders of the Thüringerwald to the north flank of the Fichtelgebirge.

The results arrived at from the preceding observations may be briefly stated as follows:—

1. From the great similarity of mineral structure as well as of fossils, from the common lines of strike and dislocation, and from many other common accidents of position, we concluded that the old rocks of all the above-mentioned regions belonged to one connected series of deposits—that they all gave unequivocal exhibitions of a Devonian system—and that none of the subordinate groups were of very great antiquity.

2. That the great series of rocks expanded between Westphalia and the Taunus might be subdivided into the following groups in a descending order:—

(1.) A true carboniferous series, partly based on mountain limestone in its ordinary form, and partly on alum slate, flinty slate, and thin-bedded black limestone.

(2.) A series of shales, slates and limestones (afterwards found to include the great limestone of Westphalia), containing many fossils identical with those of South Devon.

(3.) A very large ill-defined group, with several characteristic Silurian fossils mixed with other organic forms unknown in England.

(4.) Masses of slate of an older mineral type, and with few traces of fossils; placed by us, provisionally, in the lowest part of the Silurian or the highest part of the Cambrian system.

We wish to state distinctly that we came to these conclusions *before* we examined any of the provinces on the left bank of the Rhine, and that (with the exception of some adjustments among our lines of demarcation) we still continue to adhere to them. We may also add, that though we found no fossils in the chain of the Taunus to assist us in determining its relative age; yet were we led to conclude, by the consistent evidences of our sections, that it did not belong to the lowest of the preceding groups. But after crossing to the left bank of the Rhine we found fossil evidence sufficient to prove, that the chain of the Hundsrück (and consequently that the chain of the Taunus, which is a physical prolongation of the Hundsrück) was merely a portion of the great group above mentioned (No. 3.) in a highly altered and mineralized form. Our examination of the provinces on the left bank of the Rhine only commenced in the latter part of the summer, when we began with a series of traverses from the Hundsrück, through the basin of the

Moselle, to the calcareous formations of the Eifel. We afterwards connected the Eifel with the coal formation of Belgium ; and we twice crossed the chain of the Ardennes, continuing our traverses as far as the secondary strata which skirt its south-eastern flank from Mezières to Luxemburg.

As the general result of these observations we may state, that the successive descending groups or systems, between the carboniferous series of Belgium and the oldest rocks seen on any of the last-mentioned traverses, appeared to correspond very exactly with the successive groups (already noticed) on the other bank of the Rhine between Westphalia and the Taunus.

In making out the succession and relative age of the older rocks within the limits of Belgium, we could do little more than tread in the steps of Professor Dumont ; whose admirable memoir on the coal-field of Liège*, and whose subsequent papers explaining the structure of the great slaty region which extends from the coal-field of Liège to the Eifel and the Ardennes, are well known to the members of this Society†. While offering our homage to that geologist for the accuracy of his complicated sections, and for his able determination of a succession of natural groups of strata, we differ from him considerably, as will be seen in the sequel, in our mode of translating them into their British equivalents. The Society will bear in mind, that our leading object was to make out whether (within the country we examined) there was, below the carboniferous limestone, any group of rocks containing fossils of a type intermediate between those of the carboniferous and Silurian systems. The phænomena on the Westphalian frontier had led us to answer this question in the affirmative. But judging from the successive systems of Belgium, Professor Dumont had before answered it in the negative ; maintaining that there was in his district an immediate passage from the carboniferous to the Silurian system.

In commencing observations such as those on which we were employed last summer, the great point is the determination of good base-lines, to which the ascending or descending groups may be referred in the natural sections. We at first thought ourselves justified in assuming that the whole of the great calcareous zone of Westphalia was the exact equivalent of our mountain limestone. In doing this we were, however, misled by the geological maps of Germany ; even by that of Von Dechen, which had been just published. For we afterwards found that there are in Westphalia two distinct calcareous zones ; the upper (of comparatively small extent on the published maps) representing the true mountain limestone ; the lower (extending from the right bank of the Rhine to Hessia) being both

* Mémoire sur la Constitution Géologique de la Province de Liège, &c. Bruxelles, 1832.

† Bulletin de la Société Géologique de France, tome viii. p. 77, 1836.

in its structure and its fossils the perfect counterpart of the great limestone of South Devon.

We also assumed on the authority of the best geologists who had recently visited the country, that the Eifel limestone was the exact equivalent of the Wenlock limestone of the Silurian system. Hence we were led also to conclude, before we examined this deposit, that it must form a saddle, rising from under rocks which we had regarded as Devonian or upper Silurian. The extreme perplexity of the Rhenish sections, and the entire reversal of the formations in the neighbourhood of Münster Eifel (where we first saw the limestone) confirmed us in this error*. But we soon afterwards found that the Eifel limestone formed an undoubted trough reposing on the system of beds before alluded to—that it was very nearly the equivalent of the lower limestone of the *système anthraxifère* of Professor Dumont—and that it was in like manner the equivalent of the lower of the two Westphalian limestones above mentioned.

The great importance of determining the true age of the Eifel limestone was therefore evident. For if it were the exact equivalent of the Wenlock limestone, then would there be an end of the greater part of the Devonian system; which, during our labours in the earlier part of the summer, we thought we had so firmly established on the right bank of the Rhine, in the Hartz, and in Upper Franconia. We were, however, staggered, not merely by all the authorities which seemed combined against our first views; but, we may also add, by the many undoubted Silurian fossils, especially corals, which are found in the Eifel limestone; so that we returned to England in considerable uncertainty as to the exact result of our summer's labours. We had, however, established certain base-lines to which we could refer our numerous and laborious sections; and for their further illustration we had a large coordinate series of fossils; and out of such elements it was hardly possible to fail in establishing a true sequence of geological groups, whatever might be their classification when put in comparison with the older formations of this, or any other distant country.

Without anticipating, unnecessarily, the details of this communication, we may state, that an examination of our fossil evidence has now led to a satisfactory conclusion, viz. that there is a group of rocks, characterized by an appropriate group of fossils, in a position, geologically as well as zoologically, intermediate between the carboniferous and Silurian systems. The supposed "Ludlow Rock" of Belgium passes into the mountain limestone, and even in its lower portions does not, as far as we know, contain a single Silurian fossil: and our Eifel mol-

* It was while we were labouring under this error that one of the authors examined the inferior strata of the Boulognais. See 'Bull. de la Soc. Géol. de France,' vol. x. p. 404 *et seq.*

lusca (about which we were most anxious, and of which we had procured a fine series) were pronounced by Mr. Sowerby, the moment he saw them, to form a group analogous to that of South Devon; an opinion valuable at any time, but especially so now, while he is employed in describing and figuring the South Devon fossils. At the same time we submitted the Eifel corals to Mr. Lonsdale, who with equal confidence pronounced them Devonian. By this interpretation of the fossils we were therefore confirmed in the opinion we had formed of the age of the *système anthraxifère* before we entered Belgium; and the sequence of the formations on the left bank of the Rhine disturbed not the classifications we had first attempted to establish in the great series of older rocks on the right bank.

But for causes of inevitable delay, chiefly arising out of the long-continued ill health of one of the authors, these results would have been laid before the Society several months since. The recent investigations of Mr. Lonsdale, on the age of the Belgian limestones, having meanwhile come before the public, we need not refer to them in detail; and have now only to express our thanks to him for his most valuable assistance, and above all for the sanction he has given to our classification by his careful analysis of some of the zoological evidences on which it mainly depends.

In closing this introduction we have now to state, that the memoir will be rendered incomparably more effective than it could otherwise have been, by the valuable cooperation of M. E. de Verneuil, who accompanied us during a part of our tour, and generously determined, after having entered into our views, to render his rich stores of organic remains (collected from the Rhenish provinces) available in the illustration of this memoir. Undertaking the description of the fossil mollusks of this region, he induced the Vicomte D'Archiac (eminent like himself both in zoology and geology) to become his associate. These gentlemen have drawn and described from their collections a series of the most characteristic of the Rhenish fossil mollusca, particularly those of the Devonian and upper Silurian groups; and have furnished us not only with a scientific description of each species, but also with a tabular arrangement of them, and with general theoretical views, of high importance in determining the value of zoological evidence. In justice to these authors, we trust that the force of their descriptions may not have been weakened by translation.

Lastly, the map which is annexed (and without which the description of the Rhenish region and the sections would have been scarcely intelligible) is a reduction of the great map of Hoffmann, as improved by many recent observations of Professor Von Dechen and M. Erbreich, kindly communicated to us by the former. This map, on which we have coloured the Palæozoic rocks ac-

cording to our own classification, is chiefly intended to indicate approximately the relations of the great subdivisions of the older sedimentary deposits. Those persons who wish to study the varied composition of the rocks of igneous origin with which this region abounds, must consult the original works of the distinguished field-geologists of the Prussian school to whom we have referred.

PART I.—*Older Formations on the right bank of the Rhine.*

CARBONIFEROUS ROCKS *of Westphalia.* (*a*, *b*, and *c* of the Sections.)

(See Map, Plate XXIV. No. 6, 6[1], and 6*, and Sections 2 and 4, Plate XXIII.)

Our earliest perception of the order and succession of the older strata in the Rhenish provinces was acquired by an examination of the rocks upon the right bank of the Rhine. We shall therefore first give a very brief account of that part of the region which contains a productive coal-field, and is based upon the carboniferous or mountain limestone ; and we shall next describe, at greater length, the various strata which successively rise out from beneath it, and are thrown up into the broken and convulsed region which extends into Nassau.

Coal Measures.—This field, so rich in coal and iron, and containing the staple of the manufacturing wealth of Prussia, is surmounted on its northern boundary by the green sand and cretaceous rocks of Lower Westphalia, and to the west or towards the Rhine, by tertiary rocks and superficial detritus. That part of it which is productive is expressed by the dark colour of the Map (No. 6). It is of a triangular form, having its vertex near to the town of Unna ; while its base (which lies towards the Rhine) ranges from the neighbourhood of Elberfeldt, and passes through Kettwig and Werden to the country beyond Mülheim.

We do not profess to describe the structure of this coal-field in any detail, a task which has been already in a great measure accomplished by German geologists*. It is sufficient for our purpose to observe, that in lithological characters, in its fossils, and in its beds of sandstone and shale with their courses of coal and ironstone, it is not to be distinguished from many coal-fields of our own country. In its range from W.S.W. to E.N.E. it has been affected by many powerful convulsions, the most remarkable of which appear in the form of anticlinal lines parallel to the strike; and divide, on a ground plan, the area into triangular masses, the apices of which terminate to the E.N.E. These elevations have raised up the lower beds of sandstone and shale (6[1], of Map), which are unproductive of coal, and have thrown the overlying or productive measures into a number of troughs. The lower strata consist in part of grits (not unlike

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* See the Map and papers of Von Oeynhausen and Von Dechen—Nöggerath's Westphalia (Das Gebirge in Rheinland-Westphalen, vol. ii.).

some varieties of the millstone grit of England), which are associated with yellowish or light-coloured sandstone and shale ; and the whole series finally rises to the surface in powerful ledges on the banks of the river Ruhr, particularly near Herdecke, Westhofen, and Schwerte, etc.

In quitting the lower edges of the coal-field, we find these yellowish and light-coloured grits and sandstones (which here and there contain thin courses of coal and many impressions of plants) to be underlaid by dark grey, slightly micaceous shale, and thin-bedded, hard, grey sandstone, throughout which many small plants are distributed. This formation composes hills several hundred feet high, the strata of which rise up at great angles from beneath the coal-field. Their lowest member is composed of dark shales, which are frequently loaded with pyrites and are much worked in the extraction of alum. This "alaun schiefer" of the Germans constitutes therefore the base of the whole coal tract, from which there is a regular and unbroken sequence upwards, through the beds before described, into the overlying or productive field. The alum shale reposes on the uppermost limestone of this region—the mountain or carboniferous limestone of English geologists (6+ of Map).

The order here described may be seen in any transverse section from N.N.W. to S.S.E. along the escarpment of the coal-field, whether made at its western extremity or towards its eastern apex. The finest exhibitions of the lower beds are in the wooded hills between Herdecke and Schwerte on the N.N.W. and Hagen and Schelke on the S.S.E. ; and the same order on a smaller scale is found in the sections near Werden and Kettwig.

In their range to the E.N.E. these lower carbonaceous strata of sandstone and shale become much expanded, and cover a wide area of country to the north and east of Arnsberg, where they pass downwards into the lower calcareous zone to which we have just adverted*.

To those persons who are acquainted with the structure of Devonshire we can convey no clearer notion of this unproductive or lower coal tract than by saying, that it strikingly resembles the "*culm districts*" of that county in the colour and composition of the rocks, and in the abundant occurrence of small grass-like plants ; the species of which, however obscure, appear to us the same in the two countries. This sub-group is the "*Flötzlehrer sandstein*" of the German geologists, by whom it has hitherto been considered as the *uppermost member of the grauwacke series* ; a position which it does not occupy, as it is an integral part of the carboniferous system, being superior to the mountain limestone. (See sections Pl. XXIII. figs. 1 and 2 ; and the colour 6^1 of Map, Pl. XXIV.)

Carboniferous Limestone of Westphalia, (Mountain limestone, "*Berg-Kalk*") *with its associated bands of "Kiesel-Schiefer" and bituminous limestone.* (Map, Pl. XXIV. colour 6+, and Pl. XXIII., Sections 2 and 4, colour *d.*)

The coal-field, with its associated inferior strata above described, throughout that part of its course which extends from Cromford near Ratingen to the country north-east of Velbert, is underlaid by a strong band of limestone, which, from its position,

* *Antè*, p. 225.

structure, and included organic remains, is recognized by all observers as the representative of the carboniferous or mountain limestone of English geologists*. At Cromford this rock is fully laid open in deep quarries, in which, after the incoherent superficial deposits which cover so large a portion of this country have been cleared away, we see the strata dipping to the N.N.W. at a high angle; the ends of the beds having been truncated and reduced to a plane surface, over which the drift has been accumulated. The consideration of tertiary and detrital deposits forms no part of our present inquiry; but we cannot describe these quarries without adverting to this remarkable appearance of the sharply-truncated edges of highly inclined strata (the ends of which have been broken off and polished, as it were, into an even pavement), and expressing our conviction that such a result could not have been brought about without much violence, followed by powerful attrition on the surface of the truncated strata, more particularly when we know that the very same phænomenon is exhibited on the surface of the older rocks under the tertiary accumulations and drift in many parts of the borders of the Low Countries, and in the northern provinces of France†.

When first cleared of the overlying drift, these ancient strata often convey the false idea of being horizontally bedded, and their real position is only ascertained by cutting into the body of the rock.

The descending order of the strata of limestone at Cromford is as follows:—

1. Shale and dark limestone, the thickness and relations of which are obscured.

2. Great limestone, light grey, in beds from two to four feet in thickness: the lower beds fetid, faced with carbonaceous shale, and in mineral aspect not unlike the great scar limestone of England. In this mass are found most of the characteristic fossils, such as the *Producta hemispherica*, *P. Comoides*, Encrinites, corals, and many of the species enumerated in our list. Dolomite occurs here and there in irregular concretions throughout this rock, and is much used as a road-stone.

3. Black shale, in parts calcareous, with corallines and Euomphali in the lower beds.

4. Dark, hard limestone, used as a building and trough-stone, containing small spinose Productæ, minute Trilobites, &c.

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* See the sections and works of Hoffmann and of all preceding authorities. Our friend Von Dechen has, in his last work, 'The Geological Map of Europe,' recognized the band of rocks which immediately underlies the Westphalian coal-field as our millstone grit series, pointing out at the same time the existence of the mountain limestone beneath it; but he has merged the true mountain limestone with another band which we shall show to be inferior to it. In short, although we consider the map of Von Dechen to be of great value and generally very correct, our observations have convinced us, that, in the eastern prolongation of the carboniferous limestone, there is an error, in consequence of which the true equivalent of the *lower* coal series is not recognized in its extension over other parts of Westphalia and the Rhenish provinces.

† Striking examples of this powerful denudation, which smoothed and polished the inclined edges of the mountain limestone, were long ago described by Messrs. Buckland and Conybeare in the Mendip Hills (Geol. Trans., 2nd Series, vol. i. p. 225, Pl. XXXV. fig. 2, 1824), and the same phænomena are to be seen at Marquise, north of Boulogne.

5. Sandy and slightly micaceous shales passing into flagstone.
6. Thin course of dark grey or black limestone.
7. Shale.

The descending section at this spot is not further continuous, being interrupted by a depression and water-course; but as other limestones of very dark colour and considerable thickness rise up and occupy the northern sides of the low hills between Cromford and Ratingen, they must be considered as lower strata of the same formation, to which they are, indeed, allied, by containing some fossils which occur in the upper beds.

In tracing this band of limestone to the E.N.E., we find it well laid open beneath the incumbent drift, in the great quarries of Brock-haus, about three miles from Cromford, where the surface of the limestone gives still more striking proofs of having been subjected to great violence, and is covered with much detritus. Near Isambügel the limestone begins to rise into higher ground, and to occupy the surface of the country, being exposed in various quarries along the sides of longitudinal ravines, by which we are enabled to trace the connexion of the rock with the overlying beds, or lower members of the coal-field. The upper beds of the limestone pass into, and are intimately associated with, dark, flat-bedded, flinty slate, which in parts is undistinguishable from the black cherts of our mountain limestone. The mass is overlaid by shale and psammite; and these again by other shale beds, in which occur still thinner courses of black flinty slate, &c. The whole of these beds dip under the great series of shale, psammite, and quartzose sandstone, which we have previously mentioned as forming the base of the coal-field.

Farther on its strike the carboniferous limestone assumes a still more cherty character; and in the woody hills near Velbert the prominent feature of the formation is the prevalence of chert, charged with impressions and casts of large Encrinites, so as to be undistinguishable from the Derbyshire "screwstone." Here also we have a distinct proof that the limestone and "kiesel schiefer" dip under the black pyritous shale or "alaun schiefer" of the neighbourhood (see Pl. XXIII. Section fig. 2).

In following the calcareous bands into the valley of Regrath beyond Velbert, we perceive that they still more change their lithological aspect; becoming hard and black, and exhibiting none of those fine masses of light-coloured limestone and that profusion of fossils which we observed at Cromford, near Ratingen. The limestone, on the contrary, juts out here and there in irregular hummocks, often in vertical positions and with imperfect traces of stratification; or is bent into segments of circles, and is much altered in structure, partly from the effect of violent dislocations.

The beds which rise from beneath this limestone and occupy the tract near Tonnesheide, are highly inclined, dark-coloured shales, in parts psammitic, in parts calcareous; and these, occupying a very considerable thickness, are interposed between the carboniferous limestone, properly so called, and another inferior limestone to which we shall soon advert. We detected some few obscure fossils in these shales *beneath* the limestone as well as in those *above* it, but not in such number or preservation as to enable us to draw any conclusions from them.

By inspection of the map (Pl. XXIV.) it will be seen that, according to our views, the carboniferous limestone which thus gradually changes its character in its eastward course from Ratingen, is cut off in the valley of Regrath, north of Tonnesheide. We have indeed fully satisfied ourselves by two visits, after an interval of some weeks, that it is not curved round to form a part of the limestone of Mettmann and Elberfeldt, which we proved to be an inferior member of the series; but is distinctly separated therefrom by the shales and psammites above mentioned, which underlie it, and occupy a superficial extent of several miles*.

The upper calcareous zone, which we are now considering, is not clearly traceable at the surface through a certain distance eastward of the spot where it is cut off. In the great flexure of the coal-field to the north-east of Elberfeldt, the lower carboniferous strata are thrown about in great confusion: but in proceeding towards the eastern termination of the coal-field, where the escarpments become high and the longitudinal gorges deep, we are presented with a succession of calcareous strata which we regard as the undoubted equivalents of the carboniferous limestone; for they maintain precisely the same relations to the overlying and underlying strata which may be followed upon the strike. These calcareous beds, rising from beneath the group of shale and sandstone before described, are associated with chert and flinty slate, and thus far resemble the limestone near Velbert. In some cases indeed the flinty slate so predominates, that the bands are better designated as "kiesel schiefer" than as limestone: but here and there the calcareous matter appears in considerable force; no longer, however, in thick, but in thin, flat strata, occasionally passing into flagstone.

In the quarries near Schelke there is a passage downwards from shattery beds of sandy shale, with impressions of plants and thin courses of impure limestone, into other schists and rather thicker bands of encrinite limestone, with layers of "kiesel schiefer"; and these are repeated in several alternations.

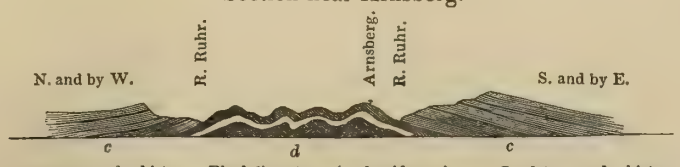
At a spot near Hemer, east of Iserlohn, and on the banks of the river Ohse, the limestone and "kiesel schiefer" beds are of a similar structure, and are still more expanded: and thence to the E.N.E. the same bands can be followed throughout

* See the alteration in Pl. XXIV. of Von Dechen's map by the insertion of two distinct limestones.

Westphalia, being extremely prominent at Arnsberg (the capital of the eastern portion of the province), which stands upon the black limestone and *kiesel schiefer*.

Fig. 1.

Section near Arnsberg.



This limestone is for the most part of a dull black colour, is extremely carbonaceous, argillaceous, and fetid, and is usually traversed by many veins of white calc-spar. In mineral characters it is so nearly identical with the black culm limestone of Devonshire, that the description of the one rock might almost serve for that of the other. It is not, however, merely in lithological structure, but still further in imbedded fossils, that this limestone is placed in parallel with that of Bideford, Bampton, Oakhampton, and Launceston (see map of Devon, Geol. Trans. vol. v. Pl. L.), being charged with *Goniatites* and *Posidoniæ*, which two genera are in Westphalia, as in Devonshire, by far the most abundant fossils of the deposit. The *Posidonia Becheri* of Devonshire (Geol. Trans. vol. v. Pl. LII. figs. 2 and 3) occurs both in this part of Westphalia and in Nassau, and we are unable to distinguish one of the flattened Goniatites of the one country from a Goniatite of the other. The "kiesel schiefer" and black limestone of Eastern Westphalia must, we conceive, represent the ordinary carboniferous limestone of Ratingen, notwithstanding a considerable difference in their respective fossils; because the one is a continuation of the other, and occupies precisely the same relative position in the series, as is proved by many transverse sections.

In confirmation of this view, we may be permitted to remark, that the mineral characters of no one formation are uniformly persistent over large areas. That sandstone may graduate into limestone and limestone into shale (or *vice versâ*), and that the leading members of a deposit may be either suppressed or entirely changed, are facts known to every geologist. It is equally well known that, with every change in the lithological composition of a rock, there is often a corresponding variation in its organic contents. Observations have often proved this fact, and it might indeed have been inferred from the known conditions of animal life*.

In tracing the course of the mountain limestone from Ratingen eastwards, we have remarked that the dominant character was rapidly lost, that chert and black carbonaceous matter began to prevail in the place of the thick, grey calcareous beds. How natural is it therefore to expect, that so great a change in the marine sediment must have produced a great change in the forms of animal life—that a change of conditions should have produced some corresponding change of species! The zoological distinction of two distant portions of the *same band* of rocks is, however, often more apparent than real, and the connecting links are generally to be traced if observations be accurate and long continued. In the strata under review, though the large *Productæ* and corals of Ratingen are wanting, yet *Goniatites* of certain forms, which are among the most distinguishing fossils of the lower carboniferous rocks, are common.

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* This fact has been dwelt upon by Mr. De la Beche in his Survey of Devonshire and Cornwall. The group of fossils in the oolitic series of Yorkshire may be quoted as an example in point; and it deserves remark, that when any part of that series (for example, the coral rag of Filey) approaches the known types in Somersetshire or Wiltshire, the accompanying group of fossils also approaches that of the corresponding formation in our south-western counties.

We found also in the black, flat-bedded limestones a small Trilobite, which we consider to be a true mountain limestone species: and these fossils are associated with the *Posidonia* so characteristic of the culm limestone of Devonshire. All these facts offer strong presumptive evidence in favour of the correctness of our views.

In following this zone upon its outcrop into the eastern districts of Westphalia, we find it bending with the enormous flexures of the inferior strata, and projecting at an acute angle to Arnsberg; whence it is suddenly deflected to the south-west, exhibiting all the contortions and undulations dependent upon such a vast curvature of the line of bearing (see map 6+ and woodcut, fig. 1. p. 233). After turning, with a south-western strike, to a point several miles south of Langscheid, it is again (along with all the neighbouring formations) bent back at an acute angle, into its former bearing, and is thence prolonged into the country near Brilon. In this part of its range it partakes of all the accidents of the neighbouring formations, and passes through a district so enormously convulsed, that all the strata through extensive tracts of country are absolutely inverted; yet does it continue to occupy its true relative place on the surface, between the mountainous regions of the older formations and the secondary deposits of the low country to the north. Continuing its range, sometimes with, sometimes without limestone, but always characterized by its courses of flinty slate ("kiesel schiefer") and its schists with *Posidoniæ*, it wraps round the north-eastern extremity of the chain of older rocks by Bleuwashe, Stadtberg and Marsberg, and is again exhibited in another parallel zone which is prolonged towards Attendorn.

Trusting to the labours of our German friends (and particularly to those of M. Von Dechen and M. Erbreich, who have constructed the geological map of this region), we have laid down the same rocks, as repeated in two parallel troughs, surrounded by the older strata, in a tract south-east of Berlenburg.

From our own observations we are also led to identify with the same group some of the uppermost strata of the environs of Dillenburg; namely, those of Herborn and its immediate vicinity (figs. 7, 8, of Sections, and colours 6^1 and 6+ of Map), where Posidonia schists, "kiesel schiefer," and bands of black limestone with *Goniatites*, are abundant. We defer, however, for a few pages our account of the complicated relations of this tract of country, inasmuch as the sections it exhibits are incomplete in the ascending order, and the beds are mineralized and changed by contemporaneous, as well as intrusive, trappean rocks. We first endeavour to ascertain the characters and sequence of the successive formations in the country bordering on the great coal-field, where the ascending sections are complete and the beds much less disturbed; and availing ourselves of this sequence, we then attempt to explain the more difficult relations of tracts of country (such as Dillenburg), where the same formations are repeated through the effects of those great undulations, to which we

have before alluded. We may however remark in this place, that beds which we consider (from their position in the undisturbed sections as well as from their fossils) to represent the base of the carboniferous system, have, on account of their mineral characters, been merged by many German geologists with the older grauwacke. The result has been, that in their published tables certain fossils of the carboniferous strata have been placed below, instead of above, the fossils of the great Westphalian limestone; which, as we now proceed to show, occupies a position intermediate between the carboniferous and the Silurian system.

Groups below the Carboniferous System.

Devonian Rocks (Map, Pl. XXIV. colour 7, and Pl. XXIII. Sections 3 and 4, colours *e* and *f*.)

We now proceed to consider the strata beneath the formation which represents the base of the carboniferous system of Great Britain. In their long range from a point north of Elberfeldt to the acute angle east of Arnsberg (where the beds are suddenly deflected to the south-west), the lower calcareous shales beneath the *kiesel schiefer* contain some peculiar reddish strata, made up of small concretions of impure limestone imbedded in a red shale. As these shales contain the *Posidonia* and some other fossils of the upper beds, we regard them as the base of the overlying system.

These strata are succeeded by psammitic flagstones, which near Schelke and at Hemer, east of Iserlohn, form a well-marked and persistent feature. Other shales of blackish colours rise out from beneath the psammites, and in them are courses of impure limestone; in which, together with flattened *Goniatites*, we begin to observe fossil shells of species unknown in the overlying formation; such, for example, as the very characteristic fossil (*Terebratula aspera*, Schloth.). These beds may therefore be considered as forming the commencement of another system, distinct from the carboniferous. We conceive that the psammites and shales are the equivalents of our upper group of the older strata of Devonshire, immediately under the culm measures*, and we shall insist further on the relations of these highest strata of our present group, when we describe the Belgian series, in which they are much more expanded than in Westphalia†.

Limestone and Shale. (*Limestone of Mettmann, Elberfeldt, Hagen, Iserlohn, &c.*)

The psammite and shale below the carboniferous system, in which we first observe fossils of new forms, constitute a passage into a lower calcareous system,

* See Geol. Trans. vol. v. pp. 643, 647.

† See Pl. XXIII. Sect. 4 and 12; also the tabular or general section 1, letter *e*.

which we now proceed to describe. The chief mass of these rocks forms the great calcareous zone of Westphalia, and is seen in numerous quarries in the environs of Mettmann, near Dusseldorf, where it crops out in highly inclined, broken, and undulating strata, and it is continued to Elberfeldt, where it occupies the northern and north-eastern suburbs of the town*. It is thence prolonged in a ridge by Barmen, whence it is expanded by undulations into two zones, which range to the north of Schwelm and reunite in the neighbourhood of Hagen. From that place to Iserlohn the limestone continues to increase in thickness, and rises into bare precipices, occupying prominent ridges between the wooded hills of the lower carboniferous strata on the one hand, and the mountains of older rocks of shale and sandstone (Silurian grauwacke) on the other.

From Iserlohn, in its prolongation to the E.N.E., this limestone is much expanded between Menden and Balve, where it forms the great salient promontory before alluded to, round which the overlying formations mantle (see map, Pl. XXIV. colour 7). From that point it is deflected nearly to Neunrade, whence it stretches in a long attenuated band to the neighbourhood of Meschede; and, after being lost for a certain distance, reappears to the north-east near Brilon. Before it reaches that place, it again increases in thickness, and is expanded over a large area by vast undulations, one of which brings it out to the surface at Warstein, among the superior strata, several miles to the north of its more general range.

In traversing the inferior rocks we find the same limestone occupying a great trough or parallel zone near Attendorn. Other bands of it (though in very different lithological condition) occur near Dillenburg; and finally it breaks out in great masses on both banks of the Lahn, striking through the heart of the grand duchy of Nassau. It would be difficult to induce any one, who judged from mere mineral characters, to comprehend how all the courses of limestone, here briefly enumerated, which appear on different zones so widely separated from each other, should belong to the same formation. But we have founded our opinion upon their persistence when followed out upon their strike, upon their changes of structure in places where there is no doubt of their continuity, upon their relations to the overlying and underlying strata, and above all, upon their organic remains, of which the most peculiar and characteristic are found throughout the several ranges above indicated.

No lithological description of the limestone, drawn from one neighbourhood, admits of general applica-

* It will be seen, by consulting the map, that this limestone, at its eastern end, occupies two zones. The northern zone extends from the neighbourhood of Wülfrath to Mettmann; and to the west of the latter place it is continued by a great flexure (characteristic of the enormous dislocations of the strata in the north of Germany) into the southern range that extends to Elberfeldt, &c.

tion*. Near Mettmann, for example, it is seen both in dark and light-coloured grey masses, partly earthy, partly crystalline. At Elberfeldt it has an altered aspect, is very irregular in its bedding, and is of a coarse granular structure, much veined, and full of nests of *dolomite* with cracks and fissures containing breccia. Parts of the rock are here loaded with, almost made up of, one species of coral, the *Favosites ramosa.* The rock preserves this altered character in the sharp and peaked ridge which extends from Elberfeldt to Weipperfeldt. At the latter place it regains its regularly stratified form, and is composed of a dark grey and light grey, hard, subcrystalline rock, which stands out in slightly inclined terraces, and is largely quarried†. The so-called *Favosites ramosa* is still most abundant; but here, as in the environs of Mettmann, we find other fossils associated with it; the most remarkable of which are *Strigocephalus Burtini, Turritella coronata* (*Buccinum spinosum*, Sowerby), *Turritella bilineata*, Goldf.‡. To the north of Schwelm, where the beds are repeated by a fault (see Pl. XXIII. f. 3.), and the limestone is quarried in thick beds, fossils are still more abundant. Of corals we see in the southern quarries a vast profusion of the *Favosites ramosa, Stromatopora polymorpha, S. concentrica*, with whole beds of the genera *Strigocephalus* and *Gypidia*§. These strata are underlaid by black and grey schists which pass downwards into psammitic grauwacke, beneath which (immediately above the town of Schwelm) are other courses of limestone of dark colour and of concretionary structure, in which occur *Favosites polymorpha, F. Spongites, F. gothlandica, Terebratula aspera* (Schloth.), with two or three species of *Spirifera.*

The same fossils are found at Hagen, and some of them in the lowest beds of the formation at Eilpe; but they are still better exhibited at Limburg and Lethmate, and in the whole of the great calcareous flexure which extends from Iserlohn to Balve (see map, Pl. XXIV.).

A similar succession may be observed in ascending the gorge of the Hünne river, from Menden towards Balve, the red shale which overlies the limestone being there much developed. This gorge resembles some of the finest valleys in the mountain limestone of England. Equally picturesque is the wider gorge, watered by the Lenne, between Lethmate and Grüne, through which the high road passes. As the descending section exhibited in this spot shows the exact relations of the great limestone, both to the overlying beds of shale and psammite and to the underlying schists and grauwacke, we here give it in some detail. (See Pl. XXIII. Sect. 4.)

* This remark perhaps applies to every great formation of transition limestone; but we may state that, without any reference to our classification, and before we had made out the relations of the great calcareous zone above described, we were again and again struck with its close resemblance to the great limestone of South Devon, especially in those places where it was most perfectly developed.

† The *Favosites ramosa*, according to Mr. Lonsdale, was so named by M. Brassart, the predecessor of M. Goldfuss in the museum of Bonn. Mr. Lonsdale has decided that this coral, which is also found in Devonshire, is not a *Favosites.*

‡ We here use the old names under which we recognised the presence of Devonian (British) types in Westphalia. The two species of so-called *Turritella* mentioned in this and many other places, have, together with some other species, been since established as a new genus by MM. de Verneuil and d'Archiac under the name of "*Murchisonia.*" (See the description of the Mollusks.)

§ *Gypidia gryphoides* of Goldfuss, *Terebratula Gryphus* of de Buch. Note by MM. de Verneuil and d'Archiac; see also *posteà* Descriptions of Fossils and Tabular List.

1. The upper mass, which rises from beneath the "kiesel schiefer" (or mountain limestone) group and overlies the *great* limestone, consists of dark shale with thin calcareous courses, in which occur small *Goniatites* and flattened *Orthoceratites*. These bands are surmounted by the red shale, grey psammite, black flinty limestone, and carbonaceous sandstones before described.
2. Black flag-like limestone,—few fossils (*Ter. aspera*, Devonian variety).
3. Dark limestone with white veins, containing numerous fossils, among which we collected a portion of the Trilobite, *Brontes flabellifer* (Goldf.), *Orthoceratites*, a small *Lingula*, and a *Producta*, like the variety of *P. depressa* * which occurs in Devonshire.
4. Great limestone of lighter grey colour, several hundred feet thick, characterized by abundance of *Strigocephali*, the shells of which chiefly appear in sections of white calcareous spar, associated with various corallines, especially *Favosites ramosa*, *F. Spongites*, *Cyathophyllum*, &c.
5. Dark-coloured lower limestone, in which we no longer trace the *Strigocephalus*, but find abundantly *Terebratula aspera*, as on the lower beds at Eilpe near Hagen.

The descending section (as seen in Pl. XXIII. fig. 4) which is exposed on the right bank of the Lenne, in proceeding from Grüne towards Altena, passes through a series of schists, flagstones, calcareous shales, sandstones, &c., in which new types of fossils begin to show themselves. These strata (to be considered more in detail in the sequel) will be shown to lie on the parallel of the upper Silurian rocks of England.

We refer to the annexed lists of the fossils of this great calcareous group above described, which will be seen to differ entirely from that of the overlying series.

In the upper limestone of Cromford, and in the thin-bedded black limestones, shales and flinty slates which take its place, we find the most characteristic fossils of the carboniferous limestone of England, and the fossils of the black culm-limestone of Devonshire; from which we infer that this culm-limestone is only a peculiar development of the carboniferous limestone. But in the lower limestone above described, the characteristic organic remains are those of the South Devon limestone, which, in a previous memoir, we have shown to be of higher antiquity than the black culm-limestones†. Thus are we enabled, through the evidence of the foreign sections, to supply geological links which have not yet been so clearly found in England; and thereby we establish comparisons which must, we presume, be of general use in the classification of the older rocks of Europe.

Devonian Rocks in their Eastern prolongation to Meschede and Brilon.

In its range to the eastern parts of Westphalia, the zone of Devonian rocks which we have described undergoes great lithological changes. The shale beds become gradually harder and more schistose, and at length pass into roofing slates; and the limestones (instead of forming a great, well-defined and thick-bedded zone)

* *Orthis rugosa.* Note by MM. de Verneuil and d'Archiac; see also *posteà* Tabular List.

† See Geol. Trans., vol. v. p. 649 *et seq.*

are in thin irregular courses, and often very highly mineralized. These great lithological changes are accompanied by various plutonic rocks, of which there are no traces in the several districts before mentioned. They consist of porphyries, greenstones, and other intrusive masses, in ridges or bands parallel to the strata*.

With the exception of a few points (where the beds are thrown off by the rocks of igneous origin), the strata of the whole elevated region are seen to dip to the south. Now the strata, which lie to the north of the great limestone, contain black and thin-bedded limestone, and dark-coloured Posidonia shales, and are obviously but the prolongation of the lower carboniferous strata of Westphalia. Yet are these strata overlaid by the great limestone, which, in its turn, is overlaid by the old grauwacke (or Silurian) rocks of the southern mountains.

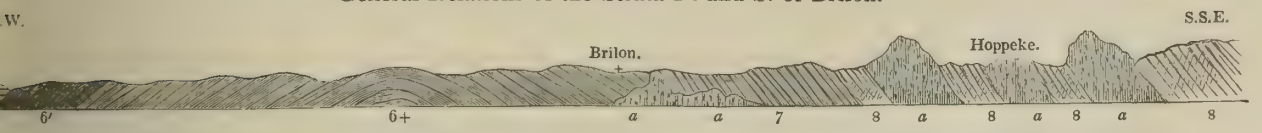
It follows, therefore, that the regular order in which we have been enabled to trace these formations through so long a space is here completely deranged, and that all the great groups are absolutely inverted, the older being incumbent on the younger.

We shall have occasion to speak at greater length upon similar phænomena on the left bank of the Rhine; therefore we need do no more in this place than register the facts as they fell under our observation.

We may, however, remark, that the occurrence of trappean rocks may perhaps suggest the cause of these enormous derangements of position, of the reality of which there can be no doubt: for we can follow the several groups along their distorted lines of strike till we trace them into the country where they are in the true normal positions indicated in the previous sections. Indeed, in the disturbed district of Brilon, we examined a section indicated by M. Erbreich, in which the lower carboniferous strata, after being reversed, fold over again and dip to the north under the cretaceous rocks (as in the accompanying woodcut).

Fig. 2.

General Relations of the Strata N. and S. of Brilon.



2. Greensand. 6′. Unproductive coal grits and shale. 6+. Posidonia and Goniatite schist.
7. Devonian beds with iron ore and fossils. 8. Slaty rocks. *a*. Porphyry, greenstone, &c.

The figures and letters are those used in the Map to distinguish the formations.

The abundance of iron ores is one of the most striking consequences of the intrusion of the porphyritic and greenstone rocks among the Devonian strata; and

* The course of these trap rocks, and of a considerable part of the limestone, has been laid down from the original surveys of MM. H. Von Dechen and Erbreich.

where these ores occur (as is often the case) with courses of limestone, the mass is frequently charged with fossils. In this ferruginous matrix the characteristic forms of *Strigocephalus*, *Goniatites*, and *Calceola sandalina*, are found near Brilon and Meschede. They are also found at Martenberg, five miles south of Stadtberg (the extreme point of these ancient rocks), where the older strata are overlapped horizontally by Küpfer schiefer, greensand, &c. (see map, Pl. XXIV.). Disturbed, therefore, as the tract has been, still each zone may be clearly distinguished —the outer (or lower carboniferous) by its small plants, its carbonaceous character, and its courses of "kiesel schiefer," black limestone, and shale with *Posidoniæ*— the inner (or Devonian zone) by its limestones, fossils, iron ores and slates: and both may in like manner be distinguished from the older grauwacke (or Silurian rocks), of which we shall treat hereafter.

Besides a complete reversal of the formations (and upon such an enormous scale), this tract exhibits a very singular insulated mass of the Devonian limestone in a highly mineralized condition at Warstein, about ten miles north of Meschede. Surrounded by hills of slaty schist, psammite and kiesel schiefer, this limestone breaks out to the surface. Its structure is very much varied, and it contains amorphous masses of dolomitic and of a veined, impure limestone, associated with hornstone and iron ore. The ore is worked in pits, some of which are upwards of forty fathoms in depth, and seems to occur in masses more or less vertical. Both in its structure and its position among the surrounding rocks, it resembles the kidney ore deposited in fissures of the mountain limestone near Ulverstone. That plutonic rocks, though not apparent at the surface at Warstein, have had their influence in producing some of these results, is a fair inference from analogy.

Some of the porphyries of these tracts, especially those of the ridges to the south of Brilon, Bilstein, and Kleine-Poppelsberg, have a character intermediate between intrusive porphyry in mass, and those varieties of finely laminated and bedded porphyritic rocks which (although they contain both concretions and crystals of felspar) are often interstratified with courses of schist and limestone, and dip along with them to the S.S.E. In the sequel we shall have to speak at greater length of the extraordinary variety of forms put on by the bedded trappean rocks, when they pass into the state of "*schaalstein*." All the sedimentary deposits in contact with the porphyries and greenstones of Brilon and Meschede are much altered; the calcareous bands being either blended with hornstones or impregnated with iron ores, while the schists and slates are often traversed by veins of lead and copper ore. The longitudinal valley of Hoppeke, south of Brilon, offers an excellent illustration of the manner in which the bands and

masses of porphyry run along like great ribs parallel to the successive sedimentary deposits*. (See woodcut 2, p. 239.)

Calcareous Rocks near Bensberg, &c. (Map, Pl. XXIV. and Pl. XXIII. Section 5.)

Under this name we include a series of calcareous deposits which are first seen on the south side of the road leading from Cologne to Bensberg (near the bottom of the hill on which the latter place stands), and extend thence three or four miles in a direction about N.N.W. to the neighbourhood of Paffrath. This range, indicated by a series of open quarries, is not along the strike of the beds, but nearly transverse to it; for the several calcareous masses, where they are distinctly stratified, strike (like all the older strata of the neighbouring country) about E.N.E.

The relations of these remarkable calcareous beds are very obscure; as they appear only here and there in low ground, and are partially overlaid by the tertiary deposits which skirt the valley of the Rhine and form a breast-work to the neighbouring hills. That they are superior to the Bensberg ridge of grauwacke cannot, however, admit of a shadow of doubt, as their fossils link them with the great Westphalian limestone. They must therefore have been brought into their present position by one of those great flexures which have so deranged the positions of the mineral masses in the Rhenish provinces, and of which we have some indications in the dips presented by the strata of the neighbouring hills. It is also clear that they took their present position long before the existence of the valley of the Rhine, or of any of the bordering tertiary deposits of brown coal and sand.

The beds near the Bensberg road are ill exposed, but abound in fossils. Crossing, however, to the north, we meet with several quarries, having nearly the same fossils, of which the beds exhibit a steady dip of more than 30° to a point about S.E. by E. These may be called the Refrath series, and evidently belong to the same

* Our friend M. Von Dechen has put into our hands a beautifully coloured geological map of the Rhenish provinces, on a very large scale, in which he distinguishes the igneous rocks at Bruchhausen, and throughout the tract around Olpe, as the common or red quartziferous felspar porphyry; those of Meschede, Brilon, Messinghausen, &c., as Labrador and Olikoglas porphyry. The latter rock displays its intrusive origin by throwing off the beds near Bredelar to the north. The oxide of iron *forms a crust* round the surfaces of these intrusive rocks, as in Nassau. In the country to the south of Brilon, extending to Wittenberg (which we did not visit), M. Von Dechen has laid down *nine parallel bands* of hypersthene rock, which are followed on the north side by three *parallel lead veins*, the whole being coincident with the strike of the strata. M. Von Dechen and M. Erbreich have also pointed out the singular fact of the persistent dip to the south, to which we have already adverted.—(See account of the map which accompanies this memoir.)

formation as the Bensberg. Their fossils present close analogies to those at the base of the great Westphalian limestone, and perhaps still closer to those in the lowest division of the Eifel limestone to be described in the following part of this communication, (*i.e.* beds of passage into the Silurian system). Beyond the Refrath series there is an interruption of nearly two miles; after which a series of thin-bedded limestones, with precisely the same strike and dip as before, break out in the quarries. These beds (which may be called the Gladbach series) are several hundred feet in thickness, and contain very few traces of fossils.

This last group is succeeded to the N.N.W. (and *apparently* underlaid) by a series of beds forming the quarries of Paffrath and Hand, which are of very complicated structure, and contain innumerable organic remains occasionally in a state of beautiful preservation. The fossils of this Paffrath group are celebrated among German collectors; and by the help of our friend Monsieur de Verneuil, who possesses a fine series of them, we are enabled to subjoin a most instructive list of species illustrated by figures. It is enough for us to state in this place, that the group of most characteristic fossils is identical with that of the great limestones of Westphalia and the Eifel.

Were we to decide by the mere evidence of the sections, we must place the Paffrath group as the lowest, and the Refrath and Bensberg group as the highest portion of the whole calcareous series above described. This arrangement is, however, contradicted by the analogous sections of Westphalia, and we may add also, by the sections of Belgium and the Eifel; and we are constrained to admit, that the vast flexure which twisted a portion of the great Westphalian limestone into the valley of the Rhine, at the same time reversed the original position of its several beds.

Assuming this reversed position, we may therefore commence a descending section near the Hand, and connect it through the intervening quarries with the lower groups of Refrath. It is impossible for us to enter on full details; but the following sketch of the sections may serve to convey a general notion of the very singular formation of limestone we are describing.

General descending section.

Paffrath group.—1. Thick, irregular, cellular beds of dark bluish limestone with partings of dark blue carbonaceous shale, with casts of *Gypidium*, *Strigocephalus*, and many corals (Hand quarry).

2. A little lower in the series (at Gronau), calcareous shales with concretions of limestone full of corals, which are readily separable from their matrix. With the marls are associated many earthy, pulverulent, yellow beds, like earthy magnesian limestone. Besides the corals, one species of *Delthyris* and two or three species of *Turritella* (*Murchisonia*), &c., occur in abundance.

3. Immediately *below* the preceding (though in a *reversed section*, and therefore on the *dip* side) are

strong beds of dark-coloured limestone, partly of earthy structure and partly subcrystalline, containing many impressions of *Strigocephalus*. The limestone beds alternate with, and seem to pass into, grey earthy marls, containing *Strigocephalus*, *Gypidia*, *Megalodon*, *Buccinum*, *Turritella* (*Murchisonia*), and many other fossils of the Paffrath group, in great abundance.

4. After a considerable interruption, and still farther on the dip side of the strata, is an open quarry which descends as far as the Gladbach group. The section is as follows:—

(1.) Dark-coloured arenaceous and impure fetid limestone (not burnt for lime), separated by carbonaceous partings, and containing small spined *Productæ*, &c., and impressions of grassy plants like those of the culm-measures of Devon.	14 feet.
(2.) Strong hard beds of dark fetid limestone with carbonaceous partings: pure enough to be burnt for lime.	20 —
(3.) Impure, porous, sandy beds, containing in their upper part an irregular bed of impure, pyritous, coaly matter several inches thick, and passing into beds of impure gritty limestone with partings of carbonaceous shale.	14 to 15 feet.
(4.) Seven or eight beds of dark-coloured limestone, burnt for lime.	10 —
(5.) Grey-coloured calcareous flagstone, alternating with meagre, absorbent, shaly matter, &c. They form a passage into the beds of our next group.....	25 —

Gladbach group.—It is several hundred feet in thickness, and hardly admits of any regular subdivisions, being essentially composed of calcareous flagstone, alternating with bands of laminated meagre marls. In its mode of bedding it resembles the upper division of the magnesian limestone near Ferry Bridge. The flagstones here and there run together, so as to form thick beds, which are sometimes cellular, like magnesian limestone, sometimes recomposed or brecciated, like certain limestones of Devonshire. The ripple-mark is common on some of the thin beds alternating with the bands of marl; and in the middle portion of the group the laminated marls almost exclude the beds of more pure limestone, which are only worked in the upper and lower divisions of the quarries.

Refrath group.—The best quarry we examined was about a quarter of a mile south of the village, and gave the following section:—

1. Strong beds of light, grey-coloured limestone.
2. Blue shale, with concretionary calcareous bands; very full of corals and shells. Many of well-known Eifel species, including *Cyrthoceratites compressus*, Goldf. (*Phragmoceratites subventricosus*, see *posteà* Description of Fossils and Tabular List), *C. depressus*, *Terebratula prisca*, &c.
3. Yellow-coloured marls, and grey and yellowish jointed limestone, alternating as far as the section was exposed to view. The whole thickness of the above beds about 200 feet.

Bensberg.—The quarries near the Bensberg road are too obscure to deserve any particular description. Among them are beds of a dark blue, hard, subcrystalline limestone, with veins of white calc-spar. The beds alternate with variously coloured calcareous shales and marls, and occasionally pass into a compact state with a conchoidal fracture. The shells and corals, though less abundant, are of the same species with those of the preceding quarry (*Refrath group*).

Considering the great length of the traverse across the strike, the constancy of the dip towards the south-east, and the great angle of inclination (on the average not less than 35°), the computed thickness of the whole Bensberg series would be enormous. That its thickness (notwithstanding the obscure position which it occupies) is very great there can be no doubt; but it is possible, from the disconnected position of the quarries, and especially from the long interruption between

the Refrath and Gladbach groups, that some of its subordinate parts may have been repeated over again by undulations, so as to convey a deceptive notion of its total thickness. Without the help of fossils it would have been impossible to attempt any classification of this great formation; by their help it becomes a most instructive example of the Devonian system of the provinces on the Rhine, and, as we think, of its passage into the Silurian system. For the illustration of the Testacea which abound in these deposits, we refer to the additional memoir and description of our companion M. de Verneuil, and of his coadjutor M. d'Archiac. (See Plates XXV. to XXXVII.)

Devonian Rocks in Nassau, &c. (Map, Pl. XXIV. and Pl. XXIII. Sections 6, 7, 8, 9 and 11.)

The grand duchy of Nassau is occupied to a considerable extent by the strata of the age intermediate between the carboniferous and the older grauwacke rocks. These strata assume different lithological characters in different districts; their more peculiar features seem invariably to be derived from their association with igneous rocks. In the mining country around Dillenburg, so celebrated for its ores of iron and copper, the deposits have some lithological features in common with the altered strata near Brilon and Meschede. But in this district the order of the deposits is not inverted, all the stratified masses being seen to dip in regular order to the S. or S.S.E.; and though much expanded by alternations with *schaalstein*, and in parts altered and obscured by bosses of eruptive rock, the following succession in descending order is observable. (See Pl. XXIII. Sect. 6 and 8.)

1st. Psammitic, thinly laminated schists and sandstones, having a character intermediate between coal-sandstones and slate-clay. These beds are charged with impressions of minute plants, and, on the whole, are not to be distinguished from the "flötzlehrer sandstein" of Von Dechen, which we have shown to represent one of the lower members of the carboniferous group*. Beneath and associated with these beds are finely laminated black schists, loaded with *Posidoniæ*, and containing also some flattened Goniatites, small Orthoceratites, minute Trilobites, and a few *Terebratulæ*. Thin courses of black limestone are detected at intervals (particularly at Erbach, near Herborn); and kiesel schiefer is there also present. Thus, from the lithological and zoological characters, there can be no doubt that, in conformity with our views, the whole represents the lower members of the carboniferous system. (See the Tabular List of

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* M. Stifft has the merit of having shown that these peculiar rocks near Herborn "were posterior to the grauwacke," asserting that they are sometimes even unconformable to the schaalstein, which invariably *underlies* them. These beds, including the schists of Herborn, are well described by him as alternating with greenstones, and as being, at the points of contact, altered into "kiesel schiefer," horn-stone, "eisen-kiesel," &c. Becher, after whom the *Posidonia Becheri* is named, considered these beds to be *grauwacke*; and the name is preserved by Stifft, although he assigns several lithological reasons for assimilating them to the *flötzlehrer sandstein* of Von Dechen, or the *rauch-sandstein* of Horel.

fossils and localities.) In the development of the strata of Herborn we have perhaps more indications of a passage downwards into the Devonian system than in any of the Westphalian sections which we examined; but the identity of the most characteristic species of *Posidoniæ* and *Goniatites* leaves no doubt of the true place of these strata in the series*.

2nd. Psammite, limestone, and shale. This group is characterized by the same fossils as at Brilon, and we therefore place it as the equivalent of the Devonian system.

3rd. Black slates of Wissenbach. Though these beds contain some fossils which might lead us to place them also in the Devonian system, the presence of several characteristic Silurian chambered shells and Trilobites induces us rather to regard them as the representatives of the highest Silurian rocks: at all events they form the beds of passage into the lower system, and will be treated of hereafter.

4th. Arenaceous flagstone and grauwacke (Silurian), which are widely expanded through all the hilly region that stretches to the north-west.

The geologist who, in troubled districts, is accustomed to disentagle the strata containing organic remains from the trap rocks with which they are associated, will have no difficulty in making out this general succession, by traversing the highly undulating and picturesque tracts which diversify the valley of the Dill, more especially its left bank. Although the above is a correct general view of the succession when the trappean and mining rocks are left out of account, it is right to give the reader a more real notion of the condition of this tract, which has been so much perforated and mineralized by intrusive rocks. To do this in detail would be to follow the example of M. Stifft, who, in describing the duchy of Nassau by separate daily itineraries, has almost filled a thickly printed volume with mineralogical descriptions of the complicated rocks which abound in every hill and vale of this country. In truth, few of these masses have much lateral persistence; so that the sections on two parallel lines, not more than half a mile asunder, would often differ in their detailed phænomena. We therefore

* The list of fossils found at Herborn, according to M. Dannenberg, is as follows:—

1. Calymene concinna, *Dalman.*

1. Ammonites expansus, *V. Buch.*
2. ——— sphæricus, *Martin.*
3. ——— priscus, *Goldfuss.*

} Goniatites hodiè.

1. Orthoceras gracile, *Blumenbach.* (Said to be also at Wissenbach.)
2. ——— scalare, *Bronn.*
3. ——— fragile, *Bronn.*

1. Mytilus veteratus, *Goldfuss.*

1. Posidonia Becheri, *Bronn.*
2. ——— longitudinalis, *Bronn.*
3. ——— mytiloides, *Goldf.* Eybach.

1. Avicula lepida, *Goldf.*

1. Pecten grandævus, *Goldf.*
2. ——— primigenius, *Bronn.*
3. ——— Münsteri, *Bronn.*

1. Aptychus antiquus, *Goldf.*

Terebratulæ, &c.

It will at once be perceived from this list, that the Pectens, Mytili, Posidoniæ and Goniatites which it contains are more near to the carboniferous than to the more ancient deposits. The only fossil *said* to be the same as a species found at Wissenbach, is so imperfect and crushed that we are convinced no identity could be established from it

refer to a section on the accompanying plate (Pl. XXIII. fig. 7), as representing one of the most illustrative of several traverses which we made, and in which the order of the groups is apparent, notwithstanding the very complicated derangements produced by the intrusive trappean masses.

The physical features of this picturesque district are quite in harmony with the varied condition of the component rocks; each woody ridge being formed of the harder plutonic and altered masses, while the valleys are excavated in the shale and "schaalstein."

The plutonic rocks consist of greenstone, both coarse and fine-grained, some examples of which have a very thick-bedded, others an amorphous aspect. Some of the masses are porphyritic, while others graduate into simple trappean "wacke," and amygdaloid, and resemble the "*basalte en boules*" of French geologists, by decomposing into concentric crusts. Laumonite and other simple minerals are associated with them. In one place the eruption of these masses has converted the sandstone into quartz rock; in another the shale in contact is in the state of jasper. In some localities they are surmounted by peculiar trappean conglomerates, in which organic remains are occasionally distinguishable, and they frequently alternate with the "schaalstein," the peculiar bedded rock to which we have already adverted, and which we will notice more at length when we describe the banks of the Lahn, where it is most developed.

On the north side of the Leiterberg, near Eibach, the limestone and shale are broken through, and thrown off both to the north and to the south; and on the south face of the hill, near its summit, the schists have been converted into a complete jasper, which is surmounted by iron ores. The limestones are for the most part in the state of "fluss-stein," a variety of altered rock in which the calcareous and trappean or ferriferous matter are blended together, and which here (as also in the environs of Oberscheld) contains beds abounding in fossils. The most prevalent character, however, of the altered deposits of this district is the very general diffusion of iron ore, which for the most part is in the state of brown oxide, and pervades the shale and limestone wherever they are in contact with the trap.

Limestones of Oberscheld, Sessacher, &c.

As the limestones of this tract of country contain several characteristic fossils in common with the zone of Brilon, we can have no hesitation in considering them of the true Devonian age. The matrix of the fossils is here also absolutely identical with that of Brilon; in many places being so ferriferous that it passes into a complete iron ore: in other places, where the calcareous matter prevails, it is used as a flux for the ores, and hence its name *fluss-stein*. M. Beyrich has described this rock as being uniformly overlaid by greenstone and supported by "schaalstein*."

* M. Beyrich is we think in error in considering this limestone to be distinct from that of the Hand, near Bensberg, before mentioned, and that of the Lahn which we shall presently describe. It is true that the localities in which peculiar mineral conditions exist may contain some peculiar species of shells;

Although this arrangement exists in the immediate neighbourhood of Oberscheld, we do not think it can be laid down as general. In fact, even in this tract there are strong calcareous courses of the same formation which are quite subordinate to schaalstein, and others which are unaltered are included in shales. The masses therefore which are associated with the greenstone ought not to be regarded as a distinct formation, but rather as altered ferriferous portions of a complicated group, with many different arrangements of its subordinate parts.

The mere list of fossils given by M. Beyrich supports our opinion, that these limestones constitute a member of the Devonian system. After mentioning the *Ammonites* (*Goniatites*) *Becheri*, Goldf., *Encrinites*, *Caryophyllia*, *Orthoceratites*, and *Trilobites*, he dwells particularly on the fact, that the *Goniatites* are so various and so abundant that the rock might be termed a goniatite limestone *.

But M. Beyrich is, we think, in error when he supposes that certain limestones of the Fichtelgebirge described by Count Münster, and to which we shall hereafter advert, cannot be of the same age as those of Oberscheld and Dillenburg, because the latter are charged with *Goniatites* and the former with *Clymeniæ*; for the very rocks described by Count Münster contain both these genera.

Copper Mines near Dillenburg.

The slates of Wissenbach and the underlying grauwacke will be described under the head of Silurian Rocks. Before, however, we leave the tract around Dillenburg, we may say a few words upon its copper-mines, for which it is as much distinguished as for its ores of iron.

According to the miners (and our friend M. Erbreich had given us similar information respecting the mines near Brilon), the copper veins traverse all the rocks of the district, being, as in every other country, more productive in one matrix than another. Thus, where we meet with the common unaltered black shale, which is much expanded to the east, the veins cease to be productive, or in miner's language, are "cut off†." When they enter the "schaalstein" the copper veins are generally productive, particularly where this rock contains much calcareous spar; but they are still richer when they pass through ferriferous strata or beds of iron ore. So uniformly do these relations prevail, that although a tolerably good copper ore is now and then found in a "schaalstein" of green colour, in which chlorite prevails, it suddenly becomes richer where the vein cuts into "schaalstein" which is impregnated with iron. The chief veins strike from N.N.W. or N.W. to S.S.E. and S.E., and the smaller branch veins are oblique to

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but the question seems to be placed beyond a doubt by the fact that the fossils of Oberscheld and Brilon are identical: for the true place of the Brilon limestone admits of no doubt, being the actual prolongation of the great Westphalian limestone.

* For the peculiar character of these shells, see the observations of MM. d'Archiac and de Verneuil.

† This rule admits not of any general application in England, though we have observed some striking examples of it. (See the 'Silurian System,' Chapters 22 and 24.)

these directions. We examined some lodes of excellent quality six to seven feet wide, which were then worked by the English German Mining Company. We were conducted to them by our intelligent countryman M. Petherwick, to whom we owe our information; and we have no doubt that these mines might be worked to great profit, even in a country where the forests alone supply the necessary fuel, were the land-transport shorter and less expensive. Up to this moment they have never been followed to any great depth; and are merely worked by horizontal galleries driven on their bearing through the sides of the steep hills which they intersect. Lead ores also occur in this district, but they are in much less abundance than those of copper*.

Devonian Rocks of the Lahn. (*Schaalstein, &c.*)

The Devonian limestones are again exhibited in broad irregular bands on both banks of the Lahn, occupying, here and there, a long elliptical area, of which the major axis extends (in a north-easterly direction) from a point beyond Wetzlar to a point on the Lahn a few miles below Dietz. The transverse axis may be placed near Hadamar, and is not more than eight or ten miles in length. Within this tract we can no longer distinctly trace the links which connect these rocks with the superior or carboniferous deposits, the *Flötzlehrer sandstein* and *Posidonia schists* not having been detected in union with them. But the whole system is surrounded by older strata of grauwacke; and hence, as seen on the map, it appears to be disposed in a great broken trough or basin. The existence of such a trough is, however, by no means indicated by the concentric dip of the surrounding strata; for on the greater part of all the transverse sections there is a prevailing dip to the south-east, which gives the calcareous series, on the south side, the appearance of plunging, not merely under the grauwacke, but also under the whole chain of the Taunus. In short, we conceive the Lahn limestones to occupy what, in a subsequent part of our paper, we call an *inclined trough or basin.*

The chief depositary strata in this shattered trough consist of limestone, sometimes associated with shale, but for the most part interstratified with vast expansions of "*schaalstein.*" Besides these laminated deposits, igneous rocks of many varieties, from true eruptive porphyry in mass, basalt, greenstone, to slaty porphyry and bedded traps, are apparent at the surface. Iron ore is also very generally diffused, and here and there is worked. The limestones, though occasionally flat-bedded dark-coloured compact or earthy, for the most part are thick-bedded, in a highly crystalline condition, and are largely quarried as ornamental marbles †. There is perhaps no stronger indication of the great chemical changes to which the strata have been subjected than the numerous mineral springs which burst

* M. Petherwick, at the time of our visit, was just beginning to use small steam-engines; and the introduction of a few Cornish miners had given a new spirit to the enterprise.

† Many of these marbles, in their colours, their structure, and their fossils, are the exact counterpart of the marbles of South Devon.

out at so many points in these parts of Nassau; for we quite agree with M. Stifft, that the springs are the still remaining evidences of former plutonic action.

Schaalstein.—This rock is so dominant and persistent on both banks of the Lahn, the limestone being often completely subordinate to it, that M. Stifft* has fixed upon it as the geological horizon by which the grauwacke and slaty rocks of the Rhine are separated into overlying and underlying deposits. Though this may be a correct observation when applied to parts of the duchy of Nassau, such a mode of distinguishing the age of strata by their mineral condition is seldom tenable through large areas. Admitting, therefore, that the peculiar rock called "schaalstein" (whether as seen on the Lahn, near Dillenburg, or near Brilon) is for the most part associated with strata of an age intermediate between the carboniferous and Silurian epochs, we cannot invariably so define its position; for some portions of it are found to alternate with beds of the underlying system, especially the grauwacke which ranges up to the north flank of the Taunus. (See Pl. XXIII. fig. 9.)

But what is this schaalstein? We answer, that this protean rock has clearly originated in submarine plutonic action. Notwithstanding this origin, it is a completely bedded rock which alternates with limestone and shale, and occasionally contains organic remains; is regularly jointed; and assumes, in short, every character common to deposits which have been formed by submarine action. After describing all the varieties in the composition of schaalstein, M. Stifft places it as a rock intermediate between schist and greenstone. The schistose varieties alternate with the underlying strata of quartzose grauwacke and contain much lime and talc (chlorite?). The greenstone varieties consist of various forms of stratified trap, sometimes fine amygdaloidal, sometimes in the form of a trap breccia, and gradually pass into flaggy and porphyritic greenstone. The prevalent varieties, however, are made up of thin broken plates of schist and chlorite, mixed up with decomposing felspar, some sand, and much *carbonate of lime*; the whole so arranged as to flake or *shale* off under the hammer, and hence its name (*schaalstein* or shale stone†). In many situations it is copiously charged with chlorite, in others with iron ore, but white calcareous spar is perhaps the most common subordinate ingredient‡.

Though finely laminated and occasionally very *shaly*, it is often thick-bedded, and is then (particularly if the lime and other ingredients be equably diffused) a very good building-stone; and it is much quarried for that purpose, as it is easily worked. Its colours are of course as various as its composition; viz. greenish, greyish and reddish. In one word, it is a plutonic recomposed rock; the description of any portion of which, taken from that end of the series where it is in contact with greenstone and porphyry,

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* Geognostische Beschreibung der Herzogthums Nassau, 1831, p. 463 *et seq.*; see also Leonhardt's Char der Felsarten, 1823, p. 747.

† According to Von Dechen, to whose beautiful inedited map of this region we have already alluded, the "schaalstein" (an equivalent or variety of the Variolite of the French) is a metamorphic rock connected with Labrador porphyry.

‡ Sir A. Crichton has described this rock, Geol. Trans., 2nd Series, vol. ii. p. 269, to which we further wish to refer the reader.

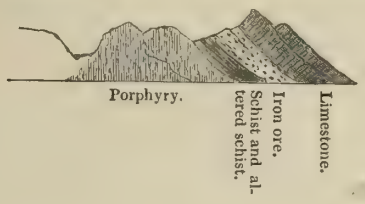
must differ essentially from that of the other extreme where it graduates into schist. When alternating indefinitely with schist and limestone, the trappean materials are less abundant than the fragments derived from the other submarine deposits with which the igneous materials are mixed up*. The calcareous matter (often in glandular and concretionary forms) may partly have resulted from contemporaneous springs highly charged with carbonate of lime, and may, in part, have been derived mechanically from the beds of limestone with which the *schaalstein* is so intimately associated.

The *schaalstein* occupies bold cliffs on the banks of the Lahn near Wetzlar, Weilburg and Limburg. (See Pl. XXIII. fig. 9.) Between the two last-mentioned towns it may be studied in all its varieties, alternating with limestone and shale, and broken through at intervals by bosses of eruptive trap which have altered and dislocated the strata. Beautiful examples of the contemporaneous and intrusive trap rocks, and their relations to the regular deposits, are exhibited in the deep picturesque gorges of the Lahn near Weilburg.

Limestones of the Lahn.—These limestones, on the whole, appear to be subordinate to the schaalsteins and schists of the tract we are considering, and are of various colours and texture. In their most unaltered condition (*e.g.* on the north side of the river opposite Limburg) they are dark grey, regularly bedded, sometimes argillaceous, and with white veins. At Carpenheim, near Wetzlar, the rock is seen in very thick beds overlying ferriferous strata, containing in parts small pisolitic and granular iron ore, which are loaded with various shells, including *Goniatites*. Porphyritic and other igneous rocks appear in the vicinity.

Fig. 3.

Left Bank of the Lahn, near Wetzlar.



Between Wetzlar and Limburg the limestone is found in several patches, sometimes with, sometimes without iron ores, which near Weilburg occur in beds; but in many instances they seem to traverse the strata irregularly, like the masses of iron ore, &c., at Warstein above mentioned.

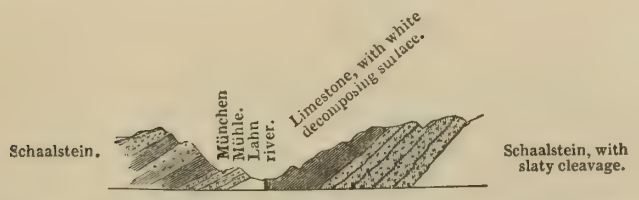
The locality at which the limestone of the Lahn has afforded the greatest num-

* No country offers finer examples than England of contemporaneous and stratified trappean rocks associated with our Devonian, Silurian, and Cambrian systems. Such rocks at one extremity of their mineral types are perfectly crystalline, at the other are brecciated and earthy, and they pass (by every shade of structure and every form of alternation) indefinitely into the aqueous and fossiliferous deposits with which they are associated. Some of these masses (which form an integral part of the highest mountains of Wales and Cumberland, &c.) can hardly be distinguished from the German *schaalstein*, except perhaps in being (on the whole) more hard and crystalline, and less calcareous.

ber of organic remains, was first pointed out by M. Beyrich*. The beds in question protrude in the slopes of the left bank of the river near the spot called München-Mühle, about two miles above Villmar, and nearly one mile above the village of Arfurth. Here the descending order of the strata is as follows:—

Fig. 4.

Left bank of the Lahn, near München-Mühle.



1st. Beds of weathered, white, decomposing limestone in a state resembling incoherent, gritty chalk marl, or calcaire grossier. 2nd. Bluish grey limestone with white veins decomposing to a buff or fawn colour. 3rd. Schaalstein, in cliffs of fifty and sixty feet in height, rising at an angle of 40° from beneath the above. The schaalstein is in parts almost crystalline, but is both regularly bedded and jointed, and also partially traversed by a cleavage oblique to the bedding.

The shells which occur in the white or upper beds identify the deposit beyond all doubt with the Devonian limestones of Westphalia. Besides the *Strigocephalus Burtini*, *Bellerophon lineatus*, *Terebratula prisca*, and several Devonian corals, such as *Favosites polymorpha* and *F. Spongites*, we find here six species of *Turritella* (*Murchisonia?*), two of which, *T. bilineata* and *T. coronata*, are very abundant near Elberfeldt. The entire absence of the *Nautilaceæ*, so common in other parts of this region where rocks of the same age abound, is remarked upon by M. Beyrich. We should however recollect, that all the fossils from the spot in question have been found in beds a few feet in thickness, and that they therefore characterize only one very small member of the Devonian system. Associated with several *Terebratulæ* of the Eifel, M. Beyrich found here an *Ostrea*, a genus which was thought to exist only in strata of much less antiquity.

On the whole, however, the fossils of München-Mühle have a true *intermediate* character, inclining rather more to the carboniferous than to the Silurian types; and we therefore infer that they lie in the upper limestones of the Devonian system.

Near Arfurth, where the Lahn runs in a great rent, the strata on the right bank dipping to the N.N.E. and those on the left bank to the S.S.W., a limestone of grey colours alternates with schaalstein and schist, and contains corals, Goniatites, and some small Trilobites. In descending the river to Villmar it

Fig. 5.

River Lahn near Arfurth.

* Owing to M. Beyrich's imperfect indication of this spot, we made two visits to Villmar before we were able to find it out. Much of the limestone along the river banks near Arfurth disintegrates into a whitish, granular, incoherent substance, like that at München-Mühle, but the latter is the only locality in which we observed many fossils. On the second occasion we were accompanied by M. E. de Verneuil.

becomes much more crystalline, and is in parts a complete marble, of greyish, whitish, mottled red and blue colours, and is much charged with corals identical with those of Devonshire.

The same rock, offering a still greater number of mineral varieties, is seen near Dietz, where the limestone is in contact with porphyry and trap. When polished the marbles of Dietz and Villmar are indeed perfectly identical with our rocks of Babbicombe and Torquay, both in colour, composition, and in the species of corals with which they abound. The *Strigocephali* and other shells characteristic of the group in the Rhenish provinces are not merely found in these marbles, but occasionally in the associated beds of schaalstein and schist.

To the north-west of the town of Dietz the Devonian limestones are underlaid by a great thickness of slaty rocks, some parts of which doubtless represent the fossiliferous slates of Wissenbach, like which they repose upon, and graduate downwards into, arenaceous flagstone and grauwacke. Near Dietz, however, these schists are much more expanded than in any other portion of the tracts we are here describing. The transverse section (Pl. XXIII. fig. 9) will help to explain the relations of the rocks of igneous origin to those of sedimentary deposit. In many places where trap rocks abound, the limestone loses nearly all traces of bedding (as for example near Hadamar), and occasionally becomes dolomitized. We consider, however, all the calcareous masses near the banks of the Lahn and within the limits of the elliptical area we have been last considering, to belong to one geological epoch; though, in a country so dislocated and obscured by plutonic eruptions, it is no easy task to readjust the different broken and altered fragments.

The previous conclusion is drawn from the structure of the great group of rocks we have been last describing, from their relation to older groups, and, above all, from their characteristic fossils. The enormous apparent thickness of the group, under any interpretation of the transverse sections, might at first sight seem to put it out of all relation to the great Devonian limestone of Westphalia and (as we shall afterwards prove) of Belgium. But we have already shown that we may rid ourselves of a part of this difficulty by the supposition of an *inclined basin* or *trough*, for the reality of which we think there is good evidence. Again, the great thickness of the group is a natural, and we might say an inevitable consequence, of the great development of the contemporaneous erupted and regenerated trappean rocks, which (both in the country of Dillenburg and on the Lahn) are so associated with the Devonian series as to form an integral portion of it.

Silurian Rocks (Map, colour 8. Sections, Pl. XXIII. fig. 1, letters *h* and *i*.)

We have endeavoured to show that certain groups of strata, above described, occupy, in the descending sections, the place of the old red sandstone of England, and that they present a group of fossils intermediate between those of the carboniferous and Silurian systems. We have therefore designated them by the name

of Devonian system. It remains for us to notice the lower groups of the descending sections, and to show the analogies they present, both in their position and their fossils, with the Silurian system.

That such lower groups exist is proved by a series of parallel transverse sections from the coal-field of Westphalia, across the Devonian strata above described, into the more elevated and rocky regions which constitute the right bank of the Rhine. Taking any one of the great roads which run to the south from Elberfeldt, Schwelm, Hagen, or Lethmate, these schistose and grauwacke rocks, with occasional calcareous courses, are seen to rise up conformably, into massive ledges, from *beneath* the Devonian system.

The succession consists in general of thin-bedded, schistose grauwacke, passing into quartzose sandstone, having more or less the character of slightly micaceous flagstones of brownish and greyish colours, very commonly having a ferruginous and sometimes a reddish tint. Occasionally these beds (*e.g.* near Iserlohn) exhibit a passage into dark grey, slightly micaceous flagstones with rippled surfaces, separated by argillaceous "way-boards," and they frequently contain a sufficient quantity of calcareous matter to constitute seams of impure limestone.

In these rocks we find a class of fossils entirely distinct from those forms which approach the carboniferous types, and of which we were gradually losing the traces as we passed through the intermediate or Devonian strata. The fossils here predominating are, several species of the genus *Pterinæa* of Goldfuss (the *Avicula* of the upper Silurian rocks), one of which can scarcely be distinguished from the *Avicula reticulata.* The genus *Homalonotus* also prevails among the same rocks, along with a great profusion of a small species of *Orthis*, a genus eminently characteristic of the Silurian system, together with new forms of *Spirifer* unknown in the overlying system (see Pl. XXXVIII., Silurian grauwacke fossils).

Black Slates of Wissenbach, &c., Pl. XXIII. figs. 6 and 7.

Besides the above-mentioned fossiliferous flagstones, certain strata are interpolated between the true Devonian rocks and the "older grauwacke," which in some districts on the left bank of the Rhine consist of flagstone, indurated shale and schist, with thin calcareous courses. Judging from their organic remains, these shales and slates must be considered as connected more with the Silurian than with the Devonian system. Of this peculiar group the transverse Westphalian sections, Pl. XXIII. figs. 1 and 3, offer only the imperfect rudiments in certain beds of shale and schist immediately under the great limestone. We shall therefore describe the group as it appears in those tracts where it is most developed.

In following the strata upon their strike to Meschede and Brilon these schists become thicker and more important (assuming a distinct slaty cleavage transverse to the bedding), and are largely worked as roofing-slates. In that district we were not, however, fortunate enough to discover in them any organic remains: but in the country of Dillenburg, the black slates of Wissenbach, which we have shown to occupy the same geological position, are loaded with fossils.

These slates, which take their name from the village of Wissenbach, distinctly rise from beneath the Devonian limestones, repose upon grauwacke, and are quarried on the slopes of the hills which form the southern side of the longitudinal valley in which Wissenbach is situate.

From the description of the "*schistes argilleux de Wissenbach*" by M. Beyrich, we were quite unprepared to find such a beautiful example of slaty cleavage, oblique to the true bedding, as is offered by these strata. So completely, indeed, has the crystalline or slaty impress obliterated the laminæ of deposit, that the latter are to be distinguished only by certain undulating and obscure lines, marked by crystallized pyrites, and inclined at about 15° or 20° to the S.S.E., while the jagged edges of the slates indicate a cleavage at the high angle of 60°, towards the same point of the compass. It is along these lines of pyrites, which mark the partings of the true beds, that the fossils have been found; and the workmen, knowing their value, carry them to their houses in the village of Wissenbach, where we purchased a considerable number of them*.

The first zoological character of these slates which strikes the observer, is the great profusion of Goniatites. Associated with them are univalve shells (Euomphali, &c.), many Orthoceratites (some of large size), Trilobites of three or four species, &c.

Besides the valuable collection of M. Dannenberg of Dillenburg†, we examined a series in the museum of Weilburg, collected by M. Sandeman; and on the last occasion we were accompanied by our friend M. E. de Verneuil. It is from an inspection of all these fossils, as well as from our own collection, that we have come to the conclusion that these slates (underlying, as they do, the Devonian limestones of Oberscheld) may be considered to represent the upper *beds of the Silurian system.*

The limestones of Oberscheld, near Dillenburg, are clearly identical with those of Elberfeldt (the *calcaire à strigocephale* of Beyrich), of which we have treated at length when describing the banks of the Lahn; but the fossils of the underlying slates of Wissenbach (see note, p. 255, and Pl. XXIII. figs. 6 and 7) indicate beyond all doubt the commencement of another zoological type. The profusion of small Goniatites on the one hand might lead us to consider these slates as of younger age than the Ludlow rocks of England; but the lobes of the species found here partake of the distinction first indicated by Von Buch, of a simple rounded lobe peculiar to the older rocks. Again, we found in this rock specimens of Cyrthoceratites and Or-

* Appearances of this kind are not uncommon among the older rocks of England. For example, the fossiliferous slates of Coniston Water Head are intersected by a highly inclined slaty cleavage; and the true beds (which are much less inclined) are often separated by thin bands of crystallized pyrites. (See Prof. Sedgwick on the Structure of large Mineral Masses, Geol. Trans., 2nd Series, vol. iii. pp. 461, 473.)

† We are very much indebted to M. Dannenberg, an excellent practical geologist and engineer, for having, on our second visit, made us better acquainted with the structure of the tract east of Dillenburg, extending from the valley of Wissenbach to the mining district of Oberscheld, Sessacher, &c.; he also furnished us with several good fossils, and a list of the species occurring in each subdivision of the region around the place of his residence, which list is given in the next page.

thoceras, as well as of certain Trilobites (*Homalonotus, Calymene Blumenbachii*, &c.), which are undistinguishable from the known Silurian fossils ; we therefore group it with the upper part of that system*.

We are aware that objections to this classification may be raised by those who draw their conclusions solely from the organic remains collected under the general name of "Eifel fossils;" among which several species, similar to those that characterize the Strigocephalus limestone of Westphalia and Nassau, are found associated with some of the same forms which occur at Wissenbach. But when analysed, this objection loses its force. In every attempt to define geological subdivisions there must be a difficulty in marking off the lowest beds of one formation from the highest of that which is inferior to it. Those strata, for example, which have scarcely any development in one tract, are frequently found to expand

* The fossils of Wissenbach in M. Dannenberg's collection are—

1. Calymene macrophthalma.

1. Ammonites subnautilinus, *Schloth.*
2. ——— Nöggerathii, *Goldf.*
3. ——— latiseptatus, *Beyrich.*
4. ——— Dannenbergi, *Beyrich.*
5. ——— compressus, *Beyrich.*
   (Spirula compressa, *Goldf.*)

} Goniatites.

1. Orthoceras regulare, *Schloth.*
2. ——— gracile, *Blumenbach.*

1. Patella Neptuni, *Goldf.*

1. Isocardia antiqua, *Goldf.*

In the more ample collection of M. Sandemann at Weilburg we observed—

1. Calymene Blumenbachii, *Brong.*
2. ——— macrophthalma, *Brong.*
3. Homalonotus, probably H. Knightii ?
4. ———Hausmanni (Calym. Hausmanni).

1. Orthoceras regulare, *Schloth.*
2. ——— annulatum, *Goldf.* Large as the Silurian species.
3. ——— calamitaceum, *Münster.* The same variety would seem to occur both in the Silurian and Devonian : our *O. annulatum.*
4. ——— dimidiatum ? Silurian system, or very near to it.
5. ——— gracile, *Blum.*
6. ———, a large new species identified by M. de Verneuil with a species from Valogne in France.
7. ——— N. S., with oblique septa.
8. ——— N. S., with a vertebrated column.
9. ——— nodulosum, *Schloth.*
10. Orthoceras giganteum ? Silurian system.
11. ———, large new species with very wide septa.
12. ———, a very singular new species, with a triangular column or lateral siphuncle, and the angles richly ornamented with raised bosses.

1. Goniatites subnautilinus.
2. ——— Nöggerathii.
3. ——— compressus (Spirula compressa), *Goldf.*
4. ———, new large species with tubercles in two rows.
5. ———, species slightly differing from *G. subnautilinus.*
6. New species.

1. Cyrthoceratites or Lituites, undefined.
2. ——— pyriformis of the Eifel.

The group of Orthoceratites and Trilobites leave in our minds no doubt that the Wissenbach schists must be considered an upper Silurian deposit. See Plates XXV., XXVII., XXVIII., &c., which have been prepared by M. de Verneuil and M. d'Archiac, and the fossils described by them.

as we follow them on their line of bearing; and with a change in their mineral character they are often seen to exhibit a peculiar change in the forms of organic life. Of this we have already adduced proof by tracing the lower zone of the carboniferous system through Westphalia (*antè* p. 231 *et seq.*) : and we now apply the same reasoning in explanation of our view respecting the slates of Wissenbach.

It has been shown, that in geological position these slates (see Pl. XXIII. figs. 6 and 7) lie between limestones containing the same fossils as those of Elberfeldt and Iserlohn, and the fossiliferous grauwacke which constitutes the chief mountain masses of the right bank of the Rhine. It has also been stated, that on the Westphalian frontier, where the whole succession is clearly exhibited, these slates have no existence, and are there merely represented by a few courses of shale, in which we found no characteristic fossils. But these underlying shales expand vastly in their range towards the east; and at Wissenbach, strata, occupying exactly the same position, assume a much more decided development, and contain that marked group of shells above mentioned which led us to our present conclusions. This view is, we think, in perfect harmony with all that we have written or observed respecting the development of the Palæozoic rocks.

In the sequel we shall endeavour to show, that the calcareous shale which underlies the great limestone of the Eifel (and we may here remark that the fossils of the shale and the limestone are always *mixed together*, and confounded in one group by the local collectors), is the equivalent of the black slates of Wissenbach. In the Eifel, however, the lithological development of this group is small, being not much more expanded than in Northern Westphalia. The observer, therefore, who drew his conclusions only from the structure of the Eifel, might (as we shall show hereafter) place the group here described in the Devonian system; while he who judged from the sections of Wissenbach and the right bank of the Rhine, and decided its age from the dominant fossil types, would consider it, as we do, to be Silurian.

Silurian Grauwacke, h^2 of coloured Sections, Pl. XXIII. figs. 1, 3, 4, 6, 7, 8, &c.

The grits, psammites, and flagstones, &c., rising beneath the slaty groups last described, contain some fossils (*e. g. Homalonoti*, *Calymene*, &c.) approaching closely to upper Silurian types; whilst other fossils of the same rocks resemble those which characterize the lower portions of the system.

Among the few fossils of this part of the series which are absolutely identical with our English forms, is the *Pentamerus Knightii*, found at Greifenstein, between Dillenburg and Wetzlar: but at this spot the section is unfortunately obscure, and the undulations and breaks are so considerable, as to destroy all sure indication of the exact geological place of the quartzose grits in which the shell occurs. They

may perhaps have been heaved up by the basaltic eruptions of the spot, which have indeed converted large portions of the arenaceous deposits into quartz rock. (See Pl. XXIII. fig. 8.)

Were it desirable, we could give many transverse sections through the lower groups of the Rhenish formations ; but the details of any one of them would be found to differ considerably from those of other parallel traverses made even at short distances. We therefore conceive that by a reference to one ideal section, in which the prominent data are generalized and grouped, we shall better explain the general relations of these older rocks than by entering into a multitude of incongruous details: and our list of fossils, with their localities, will assist in verifying the respective ages of the deposits, from whatever data they may have been previously made out.

In the tract near Dillenburg the grauwacke which rises from beneath the slates of Wissenbach (Pl. XXIII. figs. 6 and 7), and occupies the high country extending north-westward in the direction of Siegen*, is characterized by the same fossils which abound in it in so many other parts of the high regions of Nassau and Rhenish Prussia. Two species of Trilobites (one of which is not to be distinguished from *Calymene Blumenbachii*, and the other, which approaches closely to *Homalonotus Knightii*) are found in it along with numerous casts of shells. The shells are very abundant at Haiger-Sühlbach, Wildenstein, and Sossenberg†, and are associated with several species of Orthis (one of which closely resembles *O. orbicularis*), with Orthoceratites, and with several corals of the Silurian system, some of which (such as *Favosites polymorpha*) are also found in the overlying or Devonian rocks.

Again, there exist the clearest proofs, from the consistent evidence of sections, that other strata, inferior to the Wissenbach group, form the greater bulk of the grauwacke system of the Rhine. These consist of various bands of sandstone of reddish, yellowish, greyish, and whitish colours, alternating with hard grey schists, immediately underlying the fossiliferous flagstones and slates last described. Every traverse from the northern edge of Westphalia to the territory of Nassau demonstrates a similar succession. In ascending the banks of the river Lenne from Limberg to Altena, we are presented with a fine sequence of these rocks, with occa-

* M. Erbreich, chief mining engineer of the district of Siegen, and an excellent geologist, was our guide through this tract, and from him we obtained many of our best fossils. We have already alluded to this gentleman as the associate of Von Dechen in preparing the great geological map of the Rhenish provinces.

† M. Stifft enumerates many other localities in Nassau at which fossils occur. Among these are Sprinzen on the Wisper, Espa, Wisperfeldt, Hasselbron, Nievern, Altenhauser, Buch Wahlenberg, Wolfsberg, Burschen near Oberrossbach, and the Kährer-kopf, between Steinbruch and Mandeln. We regret not to have heard of these localities before we traversed this region. It would appear, however, that the fossils are chiefly repetitions of the forms we have so often alluded to.

sional seams of impure limestone, the whole rising from beneath the Devonian system (Pl. XXIII. fig. 4). The same series is seen in passing from Schwelm to Meinershagen, concretionary bands of dark-coloured impure limestone occurring irregularly throughout the zone.

It appears, after a general view of the sections, that the vast group of fossiliferous grauwacke lying beneath the schistose and calcareous beds last adverted to, is characterized not only by some of the fossils we have been enumerating and by several species of small *Orthis* closely allied to those of the Silurian rocks*, but also by certain peculiar forms which are as yet unknown to us in England; *e.g.* by the *Hysterolites* of Schlotheim, and two species of *Delthyris*, the *D. macroptera* and *D. microptera* of Goldfuss†.

In some of the lowest strata of this grauwacke, which appear in the environs of Siegen and also at Unkel and other places on the Rhine, we meet with several forms of *Orthis* (one of which has been recognized as *Orthis Pecten*, another as *Orthis flabellulum*, a third as *Orthis rugosa*) associated with a species of *Terebratula*, undistinguishable from *Terebratula Stricklandii*. This group of fossils seems rather to be characteristic of the lower Silurian rocks.

If, however, we attempt to separate the grauwacke of the Rhenish provinces into formations, we meet with insurmountable difficulties; first, because we want distinct calcareous ledges or separating lines, each characterized by peculiar fossils (as in the typical country of the Silurian rocks of England); and secondly, because several of the same species of fossils, such as the *Delthyris macroptera* and *D. microptera*, and several of the small species of *Orthis*, are found throughout an enormous vertical thickness of strata.

While speaking of the thickness of strata, we have every possible desire to guard against the exaggerated interpretation which might be put upon our words or derived from the sections we describe. The great transverse fissure in these older rocks which offers a passage to the Rhine, in exposing the strata on its abrupt sides, convinced us of the vast thickness to which the strata must have been successively accumulated; although at the same time it taught us that they have been subjected to many convolutions, breaks and repetitions. Making, however, every allowance for such phænomena, as well as for the repeated interference of volcanic rocks (with evidences of which the region is replete), we were still enabled to detect certain dominant points of flexure, and to establish certain centres of elevation, by which the thickness of the fossiliferous grauwacke of the Rhine, which we place on the parallel of the Silurian system, is proved to be enormous‡.

* For example, in this part of the series we meet with two species of small *Orthis*, one very closely allied to *Orthis orbicularis*, and the other to *Leptæna* (*Orthis*) *lata* of the Silurian system.

† *Delthyris macroptera* and *D. microptera* are considered by MM. de Verneuil and d'Archiac as one species, and as the *Spirifera macroptera* of Goldfuss.

‡ According to barometrical admeasurements of Berg Meister Schmidt, the river Sieg below Siegen is 714, and the Dill at Dillenburg 679 feet above the sea. The height of the ground between the two towns near the Kalten Eich is 1773 feet. The altitudes of the hilly region may be said to vary from

The country around Siegen may be considered as one of the great domes of elevation of these provinces, the strata of which, after considerable undulations and disturbances, plunge both to the N.N.W. and S.S.E. On the north side they are covered by the upper bands of grauwacke, flagstone and impure limestone above noticed; and to the south they exhibit, as before explained, a similar ascending order into the country east of Dillenburg, where the grauwacke flagstones are surmounted by the black fossiliferous slates of Wissenbach (Pl. XXIII. figs. 6 and 7), followed by the Devonian groups.

In a country so convulsed and so perforated by rocks of igneous origin, it would be indeed unreasonable to expect a perfect symmetry in all the details of the sedimentary deposits; thus though several points of elevation may be observed upon the Rhine, one for example near Unkel, another west of Coblentz, and a third near Caub, between Coblentz and Bingen, none of these lines of disturbance can, we believe, be traced for any great distance into the country on either bank of the river. In short, we think that many of these parallel lines of dislocation are of short lateral extension, and have thus produced a number of undulations, and sometimes of complete reversals. If the most patient investigation of the rocks on the deep fissures of the Rhine fails to teach us more than this lesson, how hopeless must it be to attempt to draw secure conclusions from any evidence to be collected in the *interior* of this region, where the natural fissures are much less clear and persistent!

These considerations lead us to say a few words upon some of the apparent anomalies of this country, and to endeavour to give some account of the position into which the various rock-masses have been thrown. The section (Pl. XXIII. fig. 4) exhibits the *Silurian Rocks* rising into mountain masses with a steady dip to the N.N.W., which carries them beneath the Devonian and carboniferous rocks; and this dip is persistent along the whole of the Westphalian frontier, as far as it is flanked by the productive coal-field: but these transverse sections, if continued further across the mountains towards the south, conduct us through certain undulations to a great irregular central area, which forms a kind of mineral axis to the whole region. From this wide area of elevation, which may be considered, in a general way, to range around the towns of Olpe, Drolshagen and Siegen, the dip is reversed to the S.S.E. And if a section be extended from any of the last-mentioned places to the Taunus (a distance of not less than sixty miles), by Dillenburg, or Wetzlar, or Dietz, the geologist will find the great southerly dip

1200 to 1900 feet, four only out of a list of eighty-three heights given exceeding 2000 feet; the highest mountain in the Westphalian country, the "Kahle-Astenberg," being 2536 feet above the sea-level; these measurements are in Paris feet. The average heights of Nassau, Siegen, &c., are therefore very much the same as those of the Silurian region. (See Mr. Murchison's 'Silurian System,' Map and Tables.)

so very prevalent, that were he to depend upon that criterion alone as a proof of superposition, he would infallibly be led to a conclusion respecting the thickness of the whole series that would be utterly beyond belief. But in this way he would be involved in a gross error; for it has been shown that beds of limestone, schist and sandstone, forming a peculiar mineral group, and having a peculiar group of fossils, are (notwithstanding the prevailing south-eastern dip) repeated at certain intervals along the supposed lines of section.

Thus the Devonian rocks and some of the lowest members of the carboniferous series, are (as we have already shown) clearly exposed near Dillenburg and Herborn, amid many trappean eruptions and countless alternations of *schaalsteins* or contemporaneous plutonic rocks (Pl. XXIII. fig. 7). Continuing the section southwards, the prevalent dip is still to the S.S.E., and yet rocks containing the *Pentamerus Knightii*, and therefore most probably Silurian, are thrown up on one point, overlaid again by the Devonian limestones of the Lahn, and containing the same fossils which we find in the zones of Brilon and Dillenburg.

Again, starting from the banks of the Lahn, where the limestones are in a state of marble, charged with numerous unequivocal fossils identical with those of the Westphalian limestone, and loaded with pure Devonian species, the dip is still to the S.S.E., an inclination which is persistent throughout nearly the whole tract extending to the foot of the Taunus. So that here again, if we trusted to vertical sections, (in a country too where trap rocks, both contemporaneous and intrusive, are for ever protruding to the surface), we should necessarily arrive at the conclusion, that the quartz rocks of the Taunus and the associated strata are not of higher antiquity than the carboniferous epoch. The fossils, however, which we collected in the slaty schists along the northern flanks of the Taunus, at Idstein, Usingen, &c., contradict this conclusion; and the quartzose rocks of the Hundsrück (a continuation of the Taunus) afford, as we shall show, similar and still more decisive evidence. These fossils are unquestionably of the same age as those of some members of the older fossiliferous grauwacke in the regions above described: and hence we are compelled to conclude, that many masses of the strata between the Lahn and the Taunus are in an inverted position; since the Devonian limestones, repeated in several parallels, seem to plunge *under* the Silurian grauwacke*.

* We are aware that M. Von Buch has long ago expressed his opinion that the Rhenish strata are not of very high antiquity. Professor Nöggerath's works are most full and instructive concerning the mineral composition of large portions of the country bordering on the Rhine, and they must always be referred to as early and most important contributions towards a true knowledge of its physical structure. M. Steininger must also be cited as having described some of the great calcareous masses we have called Devonian, as forming a basin supported by the older grauwacke. We do not think it necessary here to advert to

Though we do not wish to fatigue our readers by emptying our note-books of their details, yet having made so many traverses, we may advert to some additional illustrative districts. The Aggerthal, for example, along great part of which the new *chaussée* from Cologne to Berlin passes, lays open a considerable variety of beds of arenaceous grauwacke, schist, hard flagstone, and dull grey-coloured limestone. The limestone, occurring in large concretionary masses, is often loaded with corals. The shales which alternate with limestones are sometimes charged with the same shells that characterize the Silurian grauwacke in the country which surrounds the Eifel on the left bank of the Rhine; viz. the same small species of *Orthis* which occurs at Prüm; the small variety of the *Terebratula aspera*, so characteristic of the Silurian system (*T. affinis*, Sow.); a species of small spinose *Producta*, identical with a shell found in the beds under the Eifel limestone at Cronenburgh and at Münster Eifel; and two Spirifers common in the same tract. (See Pl. XXIII. figs. 12 and 13.)

The above species, with the coral *Favosites polymorpha*, are singularly abundant at Meinershagen and to the north of Gummersbach. Near Engelskirchen the flagstones, sometimes passing into calciferous grits, are largely quarried, and contain the *Orthis*, &c.

Between Aggerthal and the Westphalian coal-field, we met with many fossils, especially in the grauwacke north of Marienheide. They consist of several new forms, including the cast of a very remarkable, large *Terebratula*. And we ought not to omit the fossiliferous limestones, alternating with schist and sandstone, which are seen in vertical and highly inclined strata on the banks of the Lenne above Altena: at Esel for example, where we detected the *Calymene macrophthalma*, with flattened Orthoceratites in impure, black, slaty limestone; and also near Neunrade, where the beds teem with magnificent specimens of corals*.

many of the details given in his work concerning the age of the igneous rocks of Nassau (which have been much criticised, particularly by M. Stifft), our object being simply to call attention to the above fact. In his geological description of the duchy of Nassau, M. Stifft has not only presented us with a most elaborate mineralogical description of all the rocks of igneous origin, but has also, to some extent, expressed his opinion that the uppermost strata of the region, though called grauwacke by Becher and other previous authors, are, in reality, the equivalents of overlying deposits of the age of those rocks which, in the adjacent countries, support and pass into the carboniferous deposits. It is to be regretted that he has not drawn this distinction in his map: but notwithstanding this defect, and the entire want of sections, his work is of great merit considering the date of its publication, and is replete with many important and curious facts concerning the igneous and altered rocks, mineral ores, and springs of Nassau.

* This fine section is laid bare by the cuttings of the new road; and we may here remark, that the best sections we found in Westphalia were along the noble lines of new roads cut by order of the Prussian government.

The Silurian rocks of this region are, however, distinguished by one organic character, which has never been observed in deposits of the same age in England. In the Rhenish provinces the remains of land-plants occur at intervals throughout nearly the whole of the ancient series in which any animal remains have been observed. From what we had observed in Devonshire, where we found the sandstone rocks beneath the culm-measures to contain plants bearing some analogy to those of the carboniferous epoch, we were led to believe that in extending our researches to distant parts of Europe we might find the equivalents of the Devonian, and perhaps even of the Silurian system, to be also characterized by a Flora as well as by a Fauna. With the development of vegetable forms among the Rhenish rocks we find, as might be expected, traces of carbonaceous matter, one example of which has been noted in our description of the Devonian limestones near Bensberg. In the Aggerthal we again detected thin courses of carbonaceous matter; and they occurred in the vicinity of sandstone, in which we had observed impressions of stems and leaves. All the ancient rocks on both banks of the Rhine near Bonn are similarly characterized by plants. These forms are generally ill preserved, and have not yet been specifically determined by competent botanists: but it is of the highest interest to make out whether they are, or are not, identical with any species known in the overlying deposits.

One of the most instructive sections to exhibit the natural relation of the flagstones, sandstones, and schists, to the Devonian limestones, is seen in passing from Dietz on the Lahn to the baths of Ems. In this traverse we first see an enormous development of glossy slate, flagstones, &c., rising from beneath the limestone of Dietz. These rocks are penetrated by many lead veins, and are in parts much altered by the intrusion of porphyry and basalt; but the steady dip to the E.S.E., displayed in the rocky cliffs east of Obernhof (though followed by some undulations between that village and Nassau), proves that the whole of this slaty group is interposed between the Dietz limestone with Devonian fossils, and the Silurian shelly grauwacke of the baths of Ems.

Near the latter place, at Kemmenau and various other quarries, strong beds of quartzose grauwacke, sometimes completely arenaceous and alternating with schists, contain occasionally impure calcareous courses. In these are often found many fossils, which, as a group, are unquestionably Silurian. Among them we collected three species of *Homalonotus*, one of which approaches in character the *H. Knightii*, and we shall hereafter notice them as occurring in the flagstones of the Ahr, at Martelange, &c., on the left bank of the Rhine; another is what the Germans have published as *Asaphus Hausmanni*, and a third is largely tuberculated on the body like *Homalonotus Herschelii*, Sil. Syst. The same forms of Trilobite occur in the grauwacke which rises from beneath the slates of Wissenbach. These

fossils, near the Lahn mouth, are associated with two or three species of *Orthis* (one of which is very near to *Leptæna* or *Orthis lata*), and also with the very prevalent fossils *Delthyris macroptera* and *D. microptera*; they also occur in the arenaceous and schistose beds, but chiefly in the form of casts. (See Pl. XXXVIII.)

Although we do not find among these fossil casts more than two or three forms which clearly belong to the published Silurian types of Great Britain, we see at once, that the group, as far as regards its fossil shells, is not merely distinct from the carboniferous system, but also from the Devonian. A glance at the plates and lists of the fossils establishes this point.

Beds, we consider of a still older date, which rise out on the Moselle and at Unkel on the Rhine, contain a vast profusion of a few species of the genus *Orthis*, and assume very much the characters of the lower Silurian rocks, with which they have one or two species in common. But, as we have before said, the absence of clear subdividing lines, and the great dislocations and convulsions of these tracts, forbid us to dwell further upon the descending order, and to restrict ourselves to broad distinctions. All that we can say with certainty is, that, of the fossil beds in question, those which contain the *Homalonoti*, *Orthocerata*, and *Pterineæ*, indicate the upper Silurian division; while those which are marked by the prevalence of the genus *Orthis* indicate the lower. The peculiar shells *Delthyris macroptera* and *D. microptera* occur through such a deep vertical range of the series, that they cannot be considered as the types of any one portion of it. We conclude therefore, that the slates of Wissenbach, and the shales and schists of similar age which underlie the Devonian limestones on the left bank of the Rhine, may represent a portion of the upper Silurian group of England; and that the fossiliferous grauwacke of the Rhine may as a whole stand both for all the middle and lower parts of the Silurian system.

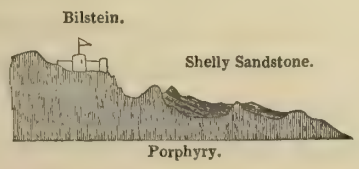
The presence of certain Trilobites and Orthoceratites, both in the Wissenbach slates and in the underlying grauwacke, teach us that some of the races of animals entombed in these rocks lived through very long periods of time. Again, we repeat that the lithological development of these deposits does not permit us to subdivide them into any well-marked physical groups; and hence they are, both lithologically and zoologically, much less distinct than the Silurian system of England.

Eruptive Rocks, Mines, Dislocations, &c.

The short account we have given of the remarkable association of sedimentary and trappean rocks in the neighbourhood of Dillenburg, may help to explain the relations of similar rocks in other mineralized districts on the right bank of the

Rhine. In the tracts north of Siegen and Olpe, bosses of porphyry and greenstone protrude at several points. At Bilstein, N.E. of Olpe, the porphyry throws off the fossiliferous strata thus :

Fig. 6.



To the south of the Aggerthal, the mining country near Runderoth is surrounded by trappean rocks. According to our friend M. Erbreich, this tract contains arenaceous flagstones and hard dark-coloured limestones (like those we saw in Aggerthal) ; but so contorted and mineralized, that the traces of bedding are often lost, and the intervals between the masses are filled with great deposits of iron ore. To the south-west of this tract are the celebrated Sieben-Gebirge, forming the most marked eruptive centre of the whole region, concerning whose basaltic and trachytic rocks volumes have been published*. In the districts of the Lahn, but particularly on its southern bank, the protrusions of porphyry, greenstone, &c., are most abundant ; and, as before said, they are accompanied by numerous springs of mineral waters. The quartz rocks of the Taunus, which form the boundary of this mineralized region, represent upon a great scale that which is seen repeatedly in smaller areas—the conversion of arenaceous strata into quartz rock. This change we consider, in common with M. Von Buch, as due to plutonic agency.

In a country so much perforated by igneous matter, which has in many places communicated a new mineral impress to whole districts, we are prepared to admit any change, however great, from the original position of the strata. In the second part of this paper, we shall allude to the great *inclined basins* of Liège, and to the methods employed by Professor Dumont of deducing the original order of superposition from the symmetrical arrangement of the groups up a horizontal section. This method might be applied in Northern Westphalia. But in certain parts of Nassau, where the formations are contorted on a great scale and often inverted—shattered by the protrusion of countless trappean rocks, and so mineralized that the very beds can no longer be distinguished—buried under tertiary deposits or covered by alluvial drift,—in many such places it would, we believe, defy the most patient observer to collect the *disjecta membra* of the country, and arrange them in any approach to symmetry.

* See Professor Nöggerath's works; also Mr. Horner's Memoir on the neighbourhood of Bonn, Geol. Trans., 2nd Series, vol. iv. p. 433 *et seq.*, 1836.

Even in those districts where the igneous rocks have not risen much to the surface, the strata are continually seen in the most convulsed positions. The banks of the Lahn between the baths of Ems and the mouth of the river offer striking examples of contorted strata. In one spot near Horein, laid open by a new road, we found the harder arenaceous beds wedging out among the slates, while the whole mass was highly inclined, broken, and contorted.

Fig. 7.

Banks of the Lahn near its mouth.

Our woodcut represents these appearances on the face of a rock not more than thirty feet high and fifty feet wide.

At the iron works still lower down the Lahn, the fossiliferous flagstones (charged with *Delthyris*, *Homalonoti*, &c.) are in vertical masses, the higher ends of which stand up like prisms of basalt; and the faces of the beds, showing the strike to be N.N.E. and S.S.W., are nearly at right angles to the general bearing of the country.

At Ehrenbreitstein (see woodcut, fig. 8.) the fortress stands upon beds dipping from 50° to 60° to the north; while the little forts a few hundred yards to the south of it are separated by a great fault, and are on beds which are almost horizontal. Further north the strata are violently contorted and nearly vertical.

Fig. 8.

Dislocations and Contortions at Ehrenbreitstein.

These are examples, on a small scale, of the dislocations to which the rocks above described have been subjected. But it would be idle for us to accumulate

many such, as they recur perpetually. We will, however, illustrate by a woodcut one more example of contortion and fracture, taken from the banks of the Moselle opposite Braideburg. Beds of arenaceous and slaty grauwacke alternate, and are violently contorted; and in one part of a lofty cliff they are broken off and covered transversely by another series of slaty beds of the same age (see woodcut, fig. 9.).

Fig. 9.

Dislocation on the banks of the Moselle opposite Braideburg.

The dislocations, such as are here noticed, and still more the contortions on a vast scale, which have inverted whole tracts of country, would have thrown such difficulties in our way, that we could not have attempted to place, even in an approximate order, the formations above described, had not the less disturbed sections in a part of Westphalia given us the master-key to the true succession of the sedimentary Palæozoic rocks of these provinces.

In traversing the Rhenish tracts, we repeatedly noticed the overlying tertiary deposits of sand, conglomerate, and brown coal, often associated (as in the Westerwald around Rennerod, &c.) with great tabular eruptive masses of basalt; but it is not our object to treat of these deposits, and they have been elaborately described by Professor Nöggerath and other German authors. Our own countryman, Mr. Horner*, has given us some new views concerning both their contents and their relations to the interpolated igneous rocks near Bonn. It is enough for our present purpose simply to state, that between these recent tertiary formations and the Palæozoic rocks, all connecting links, in the form of intermediate secondary strata, are entirely wanting in the mountainous provinces of this part of Germany.

* Geol. Trans., 2nd Series, vol. iv. p. 433 *et seq.*

PART II.

(Map, Plate XXIV., and Pl. XXIII., Sect. 10, 12, 13 and 14.)

Older Formations on the left Bank of the Rhine, &c.

We now proceed to describe the older formations on the left bank of the Rhine, including under that name,—1st. All the formations between the great coal-field of Belgium and the south-eastern flanks of the Ardennes. 2ndly. The rocks of a corresponding age which extend from the coal-field of Liège to the Eifel. 3rdly. Those from the ridge of the Eifel to the chain of the Hundsrück. The great tract of country we are considering is bounded to the north-west by the coal-fields of Liège and Namur; to the S.W. and S. by the secondary rocks of the upper Meuse, and a part of the basin of the Moselle; to the S.E. by the great Saarbrüch coal-field of the Palatinate; and to the E. and N.E. by the valley of the Rhine between Bingen and Bonn. It would hardly have been possible for us during one summer to make out the natural groups of rocks, and their relative age, in such a great and intricate country; but this task had already been accomplished by Professor Dumont, as far as regards the successive groups between Namur and the chain of the Ardennes on one side, and between Liège and the country of the Eifel on the other. It is only in describing the formations between the Eifel and the Hundsrück, and the various groups of rock which appear on the left bank of the Rhine between Bonn and Bingen, that we have to rest chiefly on our own personal observations.

Carboniferous Rocks of Belgium.

The coal-field of Belgium, like the coal-field of Westphalia, is bounded to the north by overlying cretaceous and tertiary deposits: but in endeavouring to connect the respective coal-fields with the inferior formations, we meet with incomparably greater difficulties in Belgium than are presented by the traverses through the regularly descending sections of the parts of Westphalia we first examined. These difficulties arise out of the enormous derangements of the strata; for not only are they violently contorted; but being often elevated through vertical angles of more than 90°, their relative position, as seen on the natural sections, become inverted, and we can no longer trust our ordinary criterion of superposition. For example, in crossing the Ardennes, we found between Arlon and Bastogne a prevailing dip to the S.S.E.; but, after reaching what we at first supposed the centre of the chain, we in vain looked for a mineral axis indicated by a reversed dip. The prevailing dip continued the same even to the confines of the Belgian coal-field; nor did the difficulty end there, for, with local exceptions, the whole southern skirt of the Liège coal-field is in a reversed position. Hence we might establish a series of vertical sections; from which, if we had no other evi-

dence to rest on, we might infer that the whole coal-field of Liège was inferior to mountain limestone, and the *terrain anthraxifère* of Dumont; and this system again inferior to all the slate rocks composing the chain of the Ardennes *. And how are we to rid ourselves of this monstrous conclusion?

The answer to this question is given in the details published by Professor Dumont, and to them we must refer †. But we may be permitted briefly to touch upon it, not only as a subject of great importance, but as one which admits of very imperfect illustration among the less disturbed sections of England.

When strata assume a basin-shaped arrangement, we generally find them in this Island dipping towards a centre, which is within the superficial limits of the basin (fig. 10 *a.*); and a line drawn near the centre of such basin at right angles to the beds composing it would be nearly in a vertical position. Such a line may be called the *transverse axis*; and such basins (around which the forces of elevation must have acted with nearly equal intensity) may be called *upright basins.* But we are under no necessity to limit the forces of *elevation* (or of *subsidence*, for the remark applies to both) in this manner; and we can readily suppose elevatory forces to move the masses on one side through a vertical angle of more than 90°; while, on the other, the corresponding masses are only moved through a small angle. Still we have a basin-shaped arrangement: the lines of dip converge towards a centre, which is, however, no longer confined to the superficial limits of the basin; and the *transverse axis* will be more or less inclined to the horizon. Such a one may therefore be called an *inclined basin* (fig. 10 *b.*); and it is perfectly obvious that vertical sections taken from opposite sides of it will appear directly to contradict one another.

Fig. 10 *a.*

Upright basin.

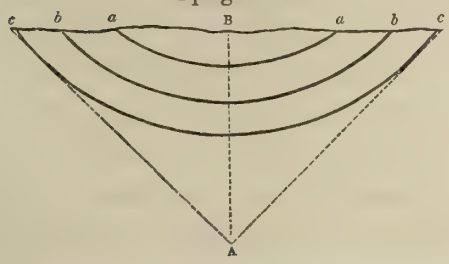
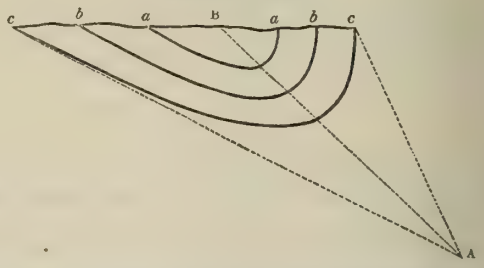


Fig. 10 *b.*

Inclined basin.



But, in addition to the vertical sections, every country gives us also, in greater or less perfection, a series of, what we may call, *horizontal sections*, by help of which the original superposition may often be determined: for it is obvious that, however great and complicated the contortion of any conformable series of strata, they must appear on the horizontal section in the actual juxtaposition they had before their disturbance. Hence they will appear at the actual surface in a kind of symmetrical arrangement, out of which we may determine a true consecutive geological series; and if we have any means of determining the true relations of the highest or lowest groups, we at once determine the true relations of the whole series. Thus M. Dumont, by the careful examination of natural sections, determined a number of natural mineralogical groups, and following them on their lines of strike, he succeeded in placing them in symmetrical position on the *map*, or *horizontal section.* Considered in this way, the coal-field of Liège became only a very complicated case of an *oblique basin*, or series of basins; and the same groups of rocks which, on the south of the field, seemed *to repose* on the coal measures, were seen, on its north

* See Pl. XXIII. fig. 12, where the upper beds are reversed.

† Mémoire sur la Constitution Géologique de la Province de Liège, 4to, Bruxelles, 1832.

side, to *rise* (in their true natural order) from *beneath* them. (See Pl. XXIII. fig. 12.) This mode of investigating the relation of contiguous groups of strata is obviously not confined to mineral basins, but admits of very general application. And before we quit the subject we may remark, that the evidence of superposition, obtained by this laborious method, cannot long be in conflict with that derived from vertical sections. For violent dislocations, such as we are considering, are but of limited extent; and as soon as we have passed beyond them, the formations are seen in their natural order, and the superposition becomes at once defined by the phænomena of a single vertical transverse section.

§ 2. *Successive Groups between the Coal-field of Liège and the Ardennes, &c.*

Leaving the Belgian coal-field, let us next consider the successive groups of strata on the side of the Ardennes, and along the sections from the neighbourhood of Liège to the Eifel. This coal-field forms the first terrain of M. Dumont, and by whatever line we make our traverse from it to the centre of the Ardennes, we find it succeeded by a second group of strata, the *terrain anthraxifère* of that author, which is composed as follows :—

An upper limestone (the mountain limestone of England), (*système calcareux supérieur*).

A group of flagstones and earthy slates (*système quartzo-schisteux supérieur*).

A lower limestone (*système calcareux inférieur*).

A series of grits, flagstones, and slates, of more complicated structure than No. 2, and sometimes having subordinate masses of coarse conglomerate (*système quartzo-schisteux inférieur*).

This *terrain anthraxifère* ranges on the side of the Ardennes symmetrically with the coal-field, but is not limited by it; as its lower members extend far beyond the bounds of the true carboniferous strata.

The preceding *terrain* passes, by absolutely imperceptible gradations, into a third group of strata (the *système ardoisier supérieur* of M. Dumont), occupying a regular zone on the horizontal section.

Again, this third group is succeeded by a fourth (the *système ardoisier inférieur* of Dumont), composed of fine roofing slates, alternating with great beds of quartzite, of more ancient aspect than the preceding, and forming the central mass of the Ardennes, as proved by following the respective systems on their lines of strike.

In the very centre of the Ardennes, and surrounded by the ordinary rocks of the 4th group, are some slates of unusually crystalline structure, and containing in some places an incredible quantity of small crystals of octohedral magnetic iron ore; in other places numerous crystals of ottrelite, or numerous red stains, apparently derived from some decomposing ferriferous mineral. These peculiar slates, and the associated quartzites, are placed by M. Dumont in a 5th group. Led by the physical structure of our own country, and the fact that beds of porphyry appear among them in the great gorges of the Meuse, we should rather consider them as a lower and altered portion of roofing slates of the Ardennes. This is, however, a question of little moment; for these crystalline slates form a geological centre; and in whatever direction we take our departure from them, the

successive groups (as far as they are exhibited) are in the ascending order of the series above given.

For example, if from this centre we ascend the gorges of the Meuse towards Mezières, we pass in succession over the 4th and 3rd groups, when the series is interrupted by the unconformable junction of secondary strata. If, on the contrary, we take any line of traverse down the basin of the Meuse, toward the Belgian coal-field, we cross in regular ascending order the several groups of deposits (before enumerated), ending with the carboniferous system. Now these groups or systems are arranged symmetrically, are conformable to, and pass into, one another. They can therefore only belong to a consecutive series of deposits; and as we are certain of the relative ages of the carboniferous system, and that which is next in order, we at once conclude that we have from that system, to the very centre of the Ardennes, a true *descending section*. And thus we bring the geological sequence into harmony with the mineralogical phænomena; which never could have been done, for reasons already stated, by examining the superposition of the beds on any one line of traverse.

The central crystalline schists, above mentioned (*roches aimantifères*, &c., of M. Dumont), do not form any distinct continuous ridge, but break out here and there, nearly along the prevailing line of strike, and with the relations above indicated. Their last appearance towards the N. E. is in a wild mountainous tract near Recht, a village eight or ten miles south of Malmedy; and taking these slates as a centre, if we make traverses from them to any part of the Liège coal-field, we cross the 4th, 3rd, and 2nd groups, above enumerated, and so pass into the 1st or carboniferous system. The groups are conformable, continuous, and pass insensibly one into another. They must therefore belong to an uninterrupted geological series; and we determine the superposition, as before, not by the evidence of vertical sections, but even in some cases in direct opposition to it; for the magnificent sections seen in the various gorges, as we approach the coal-field of Liège, generally exhibit an inverted series*.

In making another traverse from the same geological centre, near Recht, to the limestone of the Eifel, we cross, in regular ascending order, the two zones of roofing slate (groups 4 and 3); and then, after passing over the lowest division (*système quartzo-schisteux inférieur*), finally arrive at the lower limestone of Dumont's second system (*terrain anthraxifère*). Thus we have another proof of the truth of the greater part of our geological sequence; and, as far as the section is complete, we obtain also a new proof of the true order of superposition: for on the Eifel side the beds are no longer inverted; and the evidence derived from considerations of symmetry in the horizontal distribution of the mineral masses is in perfect accordance with that which is given by the clear vertical sections†.

* See Plate XXIII. fig. 12.

† See Pl. XXIII. fig. 12. and fig. 14.

So far we have been explaining the views of Prof. Dumont by applying them to lines of section which we personally examined. With very limited exceptions we adopt his successive mineral groups; and we think, beyond all shadow of doubt, that he has (somewhat in the manner pointed out) determined their true order of superposition, which we shall therefore assume at once as a matter proved. Had not his methods been so very different from those we commonly have recourse to in this country, we should not so long have dwelt upon them; and we can only further refer our readers to his published works. Our next object must be to bring these several groups or systems into comparison with their British equivalents; and this must be done chiefly on the evidence of fossils.

Description of the successive Groups.

1. We need not dwell on the carboniferous system of Belgium, because there are no doubts respecting its relations. For the same reason we may pass over the *upper limestone* of the *terrain anthraxifère*, as it is the undoubted equivalent of the English carboniferous limestone. It may seem strange to an English geologist, that this limestone should have been grouped in a system inferior to the carboniferous: but in Belgium we have no beds of coal alternating with the limestone, and forming a passage into the richer and higher part of the coal-field; and the upper and lower limestones have so many analogies, especially in lithological characters, that, with reference only to Belgium, we think this classification by no means unnatural. It is hardly necessary for us to add, that, as English geologists, we should of course strike off the upper limestone from the *terrain anthraxifère*, and group it with the carboniferous system.

2. The next descending group is the *système quartzo-schisteux supérieur*, which we must describe very briefly, as our limits allow of very few details. It is separable into two very distinct members,—an upper and a lower. The upper division is chiefly characterized by an open-grained, yellowish sandstone (*psammite de Condroz*), sometimes passing into a hard grey micaceous flagstone, not unlike a coal-measure flagstone. The yellowish beds are meagre to the touch, and are generally rather soft and earthy, and have subordinate bands of greenish grey indurated shales or mudstones: among them also are rarely found some bands of a rotten cellular psammite, with many casts of fossils, among which we at once distinguish *Terebratulæ*, three or four species of *Spiriferæ*, and small investing corals. The higher parts of this upper division are generally harder and thicker-bedded than the lower; but on approaching the mountain limestone they are seen to alternate with courses of shale. The shales also begin to alternate with beds of limestone; and the two systems are thus linked together by a gradual passage, showing that the deposits were absolutely continuous. A few obscure impressions of plants are found in this upper division; and its thickness in the neighbourhood of the Chateau d'Halloy may be about 1500 feet. As some of its fossils cannot be distinguished from those of the carboniferous system, into which it forms a true passage; and as it does not contain, as far as we know, a single Ludlow rock fossil, it is impossible to consider it as older than the upper part of the old red sandstone, and indeed it is very doubtful whether some English geologists would not arrange it with the mountain limestone.

The *lower division* of this system (*système quartzo-schisteux supérieur*) is also composed of alternating beds of psammite, and of an indurated shale or earthy schist; but the latter is more abundant than the former; and indeed this whole inferior group is characterized by the great quantity of greenish-grey,

or dirty greyish-green, earthy schist or *mudstone*, extremely resembling many of the most characteristic varieties of Ludlow rock*. Its whole thickness must be very great, though difficult to compute correctly from the number of undulations. Through the intervention of beds of hard grey sandstone it passes, in some places, into the upper division of yellow psammite (above described): and near the same part of the series are sometimes seen calcareous bands with numerous organic remains, especially Terebratulæ and Spirifers. Still lower in this division (for example, on the road from Liège to Spa, and on the road from Liège to Marche-en-Famenne) are found calcareous bands, and beds of calcareous shale, sometimes of a reddish colour, with many calcareous concretions, and associated with these are numerous organic remains. The species are enumerated in the accompanying lists. But we may observe, by the way, that neither in the yellow psammites of the upper division, nor on any part of the calcareous and fossiliferous earthy schists of the lower, did we find a single Upper Silurian fossil. Coupling this fact with the passage of the upper part of the formation into the mountain limestone, we reject any inference which may be drawn from a mere mineral resemblance of the lower beds to certain portions of the Ludlow rock; especially when we consider how inconstant are these mineral characters in our own country, and how utterly unlike the upper Silurian rocks of Westmorland are to those of Shropshire, Herefordshire, &c.

3. Having thus, we think, proved that the second member of the *terrain anthraxifère* of Prof. Dumont is clearly not the equivalent of the Ludlow rock of the British Silurian system, we now proceed to notice the two inferior divisions, which are considered by him as the equivalents of the Wenlock limestone and Caradoc sandstone. The *lower limestone of Belgium* rises immediately from beneath the formation last described, without any break of continuity or any appearance of interrupted sequence. It is a formation well defined in character and of great thickness. It is distinguished from the mountain limestone by its position, and partly also by its structure; for it is, on the whole, closer grained, and has often a kind of scaly fracture, resembling, in that respect, certain varieties of South Devon limestone. It sometimes also puts on a kind of slaty structure, often seen in old limestones alternating with schistose rocks, but very seldom found in true mountain limestone. It is also entirely distinguished from that limestone by its corals (*Favosites polymorpha, Stromatopora concentrica,* &c.); in which respect it is identical with the South Devon limestone, and also with the great lower limestone of Westphalia, described in the former part of this paper. Its colours are however very variable; and it has dark carbonaceous beds (hence its name *anthraxifère*) which burn to a white lime, and are not distinguishable from common varieties of carboniferous limestone: and moreover it has, in a few places, like that limestone, thin-bedded and close-grained masses of a dark colour and conchoidal fracture, which are polished for black marble. Such is the position, and such are the prevailing characters of the lower Belgian limestone. Its fossils are given by M. Dumont, and have been discussed by Mr. Lonsdale; and appeared to us unequivocally the same (considered as a group) with those of the great lower Westphalian limestone (of Elberfeldt, Iserlohn, &c.). Hence all the arguments by which we endeavoured to prove the age of the latter, may here be applied to determine the epoch of the former. In short, it is in position on the sections, in its structure, in its great extent, and in its group of fossils, a true Devonian limestone: and we shall further recur to this subject, after we have, in the progress of this paper, noticed the Eifel limestone.

4. We must in the next place shortly notice the lowest formation of the anthraxiferous system of M. Dumont. It is essentially composed of psammites and schists. The psammites pass into beds of hard, siliceous flagstone and strong beds of gritstone; and in some places (chiefly in the upper portions of the formation) into beds of coarse conglomerate, which are sometimes of a grey, and sometimes of a brownish red

* It was the lithological resemblance of these beds to the Ludlow rock which induced M. D'Omalius D'Halloy and M. Dumont to identify them with that deposit.

colour. The schists pass into arenaceous shales alternating with flagstones; and at their lower boundary pass into slaty masses which blend themselves with, and are inseparable from, the upper slate rocks of the next lower system (*système ardoisier supérieur* of M. Dumont).

Considered as a whole, this formation is harder and more siliceous than the upper quartzose schists above described. It is also distinguished (though to this remark there are many exceptions) by the red colour, not merely of the conglomerates above noticed, but also of the flagstones and shales, which sometimes are both red and variegated*. These colours are most prevalent within a certain distance of the limestone, and disappear in the descending sections. The flagstones and associated arenaceous shales are, however, often of a grey, yellowish-grey, and greenish-grey colour, and sometimes pass into the condition of an earthy *mudstone*, like the upper Silurian rocks of England. Occasionally (though not commonly) traces of an oblique cleavage may be seen among the more slaty masses, and the whole is often divided by a double system of joints. And we may remark, that such joints cut through the conglomerate beds by regular plane surfaces which continue their course through the imbedded pebbles without any interruption; thereby showing that the force which produced the joints was of the nature of a mechanical tension (by what cause produced we do not now inquire), and not derived from any direct molecular action of the particles composing the jointed masses.

The formation is of great thickness in Belgium; but, as far as we are able to interpret the sections, it is vastly thicker, and also more calcareous and fossiliferous, in the country south of Westphalia, and also in the country surrounding and dipping under the Eifel limestone.

For the fossils of this formation (which are difficult to procure, and of which we brought away hardly a single specimen) we must refer to the lists of M. Dumont; and also to our lists, derived from rocks of the same age, beyond the limits of the country we are now considering. As we can show that the formation immediately below it is unquestionably Silurian, we are justified in placing it between the undoubted Devonian and Silurian rocks. But where shall we draw the line of separation? We shall endeavour to find an answer to this question in evidence afforded by the sections of the Eifel and the Rhenish provinces, which are more complete. Meanwhile we may observe, that the mineral character of the red conglomerates which appear below the inferior limestone, formerly led M. Dumont (to whom we may add M. Rozet and other observers) to regard them as the representatives of our *old red sandstone*. We have not any great objections to this view; and adopting it hypothetically, we should place the conglomerates and the coarse hard beds which occur in the upper part of the formation we are now discussing at the base of the Devonian system (or old red sandstone). On this view, it follows that the inferior Belgian limestone and all the overlying deposits up to the base of the superior (or true mountain) limestone must represent the middle and upper portions of the old red sandstone. Nor do we think it any objection to this determination, that the assumed base line cuts through a *natural mineralogical* group, so as to place its upper and lower portions in two distinct systems; for the same objection may be made to the zoological subdivisions of the deposits in the Paris basin, as well as to some of the lines separating the secondary formations of England.

We endeavour to show that the transition formations of the Continent, commencing with the mountain limestone and descending to the lowest fossiliferous deposits, form one vast uninterrupted sequence, with no universal and well-defined subdivisions: and we also attempt to show that the natural groups of fossils follow a similar law. The mineralogical groups and the fossil groups being both founded in nature, and presenting an actual sequence, agree in the general and broad con-

* See Plate XXIII. fig. 12.

clusions to which they lead us; but they naturally and necessarily differ when we come to questions relating to minute subdivisions.

The actual sequence of the deposits, and their relative order in an ascending or descending series, can only be made out, in the first instance, by the examination of true mineral groups and natural sections. And such groups are of inestimable value in making out the relations of physical regions, either actually continuous, or not very widely separated from one another. But as all such groups are the results (at least in a great measure) of mere local mechanical causes, we might infer hypothetically (what indeed we know by experience), that even among formations undoubtedly of the same age, an agreement in the minute subdivisions is not to be looked for. We do not find such an agreement between the subdivisions of the Silurian system in Herefordshire, Shropshire, and North Wales; still less do we find any exact mineralogical agreement of these subdivisions, as developed in a part of Lancashire and Westmorland.

In questions of doubt, the mind naturally seizes on the first analogies that present themselves; and we think it was perfectly natural for Monsieur D'Halloy and Professor Dumont to classify the three lower members of their *terrain anthraxifère* respectively with the Ludlow, Wenlock and Caradoc formations of the Silurian system: and we were so far misled by the beautiful analogy which seemed to be presented by the mineralogical development of the region, that we were disposed to adopt this view after our *first* examination of the Belgian sections, though it threw our previous classifications on the right bank of the Rhine into great difficulties. Our present classification not merely relieves us from these difficulties, but appears to be based on a sound induction from all the facts of the case; and with this remark we pass on to a brief consideration of the lower Belgian formations.

5. *Upper Division of the Terrain ardoisier of the Ardennes, &c.*—This formation is, in its upper members, blended with the base of the formations already noticed, and its lower members graduate insensibly into the central and more crystalline slates of the Ardennes (or *système ardoisier inférieur*). It has been shown by Professor Dumont to occupy the position thus indicated; to be wrapped round the central slate rocks of the Ardennes; and in a similar position to surround the central masses that appear in the prolongation of that chain towards the Eifel. As our several traverses only tended to confirm the general justness of his views, we accept them without hesitation. But there is another question, what are the British equivalents of this formation? In replying to it we can only appeal to our fossils, unfortunately very few in number, and to the fossil evidence offered us by Professor Dumont and some other geologists. But we shall afterwards confirm our views by an appeal to other evidence, derived from the fossils in analogous beds under the Eifel limestone; and by the general structure and relations of the Rhenish provinces (out of the limits of Belgium), in which fossils are more abundant.

In the first place, then, we found in several parts of this formation large winged Spirifers (*Delthyris macroptera* of Goldfuss, &c.) of species unknown in England, but analogous to forms which, on the right bank of the Rhine, we have shown to be associated with known Silurian fossils. For example, specimens of this kind have been found at Houffalize, Wiltz, Weidinza, Longwily, &c., places on the

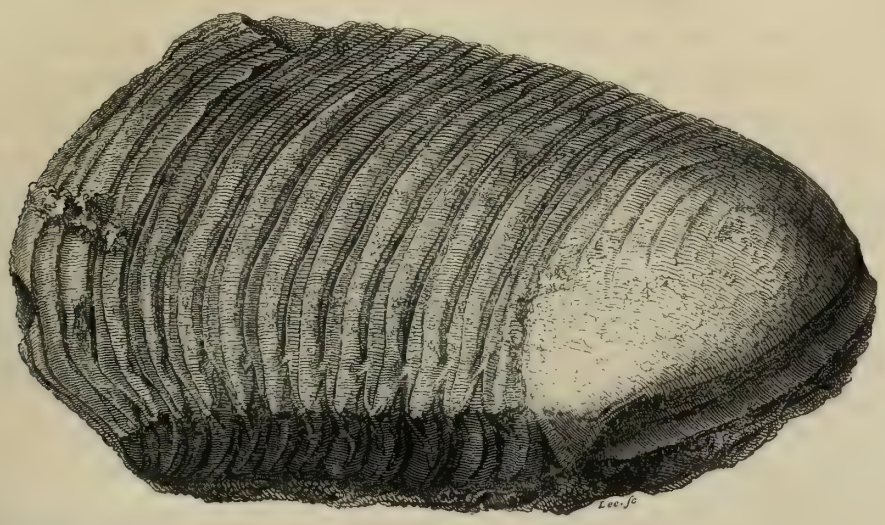
formation we are considering. Again, at Martelange, on the south flank of the Ardennes, and in this upper zone of slates, we find several species of fossils; *e. g.*

(1.) Beautiful starred Encrinites, like those (figured in our Devonian paper) which were found near Looe in Cornwall, in a rock considerably inferior to the Plymouth limestone*.

(2.) Two species of *Orthoceras*, and one we think identical with *Orthoceras articulatum* of the Ludlow rock.

(3.) A trilobite not easily distinguished from *Homalonotus Knightii* of the Ludlow rock. (Fig. 11.)

Fig. 11.



These fossils (and some others which we saw in the museum of Namur through the kindness of Professor Cauchy) first led us to think that the slaty zone we are considering was partly Devonian and partly upper Silurian; we afterwards, however, modified our opinion, finding that certain forms found in only the highest part of the Silurian system in England, are more widely diffused, and descend into the lower part of it on the Continent. On the whole, we conclude, partly on direct evidence and partly on analogy, that the upper slate zone (*système ardoisier supérieur*) of Belgium and the Ardennes (and with it we would also class the lower part of the formation immediately overlying it) is of the Silurian age, though its mode of development offers us no means of separating it into distinct groups; and thus the whole fossiliferous system, from the mountain limestone downwards, forms one connected and natural series.

6. It is in vain for us to enter on any details respecting the oldest slate rocks of the Ardennes, and of the country between Liege and the Eifel, as we have not obtained a single fossil from them. As, however, they form only the last term of a connected series and immediately succeed the Silurian system, we see no reason for placing them lower than the upper Cambrian system. Their mineral character opposes no difficulty to this view, as we know by the analogies presented by the slate rocks of our own country, how impossible it is to determine their age by mere considerations of mineral structure.

Before we quit the consideration of the Belgian rocks, we may, however, notice the beautiful structure of the old slates of Recht, which form the axis of the country south of Malmedy†. The slates are obtained by planes of cleavage distinct from the beds, and sometimes dipping to an exactly opposite point; and the true bedding is marked

* See Geol. Trans., vol. v. Pl. LV. fig. 8.

† See Section 12, Pl. XXIII.

on the slates by the usual appearance of a *stripe*, or sedimentary line. In addition to the main cleavage there is in some of the quarries a distinct *second cleavage*, indicated by an infinite number of minute *striæ*, which may be traced even through the minutest portions of the slates. This shows that the *striæ* and *second cleavage* were derived from a true molecular action, quite different from the mechanical tension which has so often produced large open joints. The second cleavage is not sufficiently perfect to produce any roofing slates, and indeed in some measure injures those obtained from the first and ordinary cleavage; for all the slates have a tendency to break off at the regular planes presented by the second cleavage. Large masses of the rock had, in some places, slid off in the quarries at one of the second cleavage planes; which, being highly inclined to the horizon and nearly transverse to the bedding, gave the appearance of regular *dip-joints*. But they are not *joints* in the common acceptation of the term, and they are cut at a small angle by nearly vertical true *dip-joints*; which, as usual, intersect both the beds and cleavage planes without deviating from their course. We have never remarked phænomena such as these in Cumberland, Lancashire, or North Wales; but in a previous paper we noticed similar (though in their kind less perfect) appearances on the coasts of Devonshire and Cornwall*.

Eifel, Banks of the Rhine, Basin of the Moselle, &c.

We have before stated, that if we commence with the oldest slate rocks near Recht, and make two ascending sections, one to the lower limestone of Belgium, and the other to the limestone of the Eifel, we pass through the same succession of deposits†. Hence we might conclude, on the general evidence derived from this physical structure (and the conclusion is also borne out by the fossils), that the two limestones are on the same parallel. On this point, indeed, there seems to be no difference of opinion. Now in the whole region, extending through the basin of the Moselle to the Hundsrück, and on the left bank of the Rhine from Bonn to Bingen, there are no repetitions of any great limestone groups; such as are seen in the Eifel, and on the other bank of the Rhine along the drainage of the Lahn, and in the mineral country of Dillenburg. In short, all the deposits of the regions above alluded to, on the left bank of the Rhine, are inferior to the Eifel limestone, which may therefore be assumed as a fixed point of departure in the *descending sections*.

One of the chief masses of this limestone (see Map, Pl. XXIV.) occupies an irregular elliptical area, the longer axis of which extends from a point a little S. of Schönecken to a point about two or three miles N.E. of Münster-Eifel, and is surrounded by the formations which are immediately inferior to it. Its true position

* See Geol. Trans., vol. v. pp. 656 and 658.

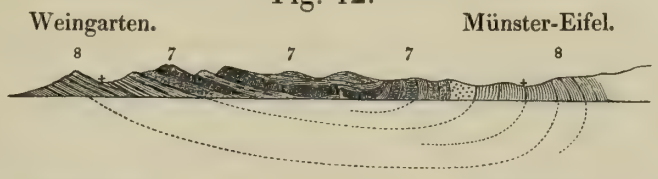
† See Pl. XXIII. fig. 12 and fig. 14.

is very clearly exhibited in a section* we have drawn from the Schnee-Eifel to the hills of Schönecken. The limestone is not, however, expanded continuously through the whole elliptical area, but is thrown into violent undulations, which here and there bring the lower rocks to the surface; so that it becomes resolved into three or four distinct and irregular troughs (see Map, Plate XXIV. and Sections 12 and 14, Pl. XXIII.), all presenting the same general relations.

Again, it has been pierced by comparatively modern volcanic vents, and is interrupted by volcanic cones and the remnants of streams of lava; and in some places, especially on its eastern limits, it is covered up for miles together by lava, cinders, scoria, and other volcanic ejections. But these materials, though they greatly add to the difficulty of making out the details of the country, do not disturb the general relations of the formations through which they have forced a way to the surface.

Near Münster-Eifel, in consequence of the extreme contortions, all the formations, for several thousand feet of thickness and a range of several miles, are in a reversed position, as indicated in the woodcut, Fig. 12.

Fig. 12.



Strata in order. Strata inverted.

7. Devonian limestones, &c. 8. Silurian grauwacke, &c.

The figures 7 and 8 are those used in the Map to distinguish the formations.

This anomaly must have been produced by disturbing forces which acted during ancient periods, long anterior to the comparatively modern volcanic vents; and as we follow the beds along their strike, the limestone is seen gradually to recover its natural position; so that near Sötenich it occupies a trough as clearly defined as the one we have indicated near Prüm and Schönecken. (Pl. XXIII. fig 14.)

The limestone is of very great thickness; for on some of its outskirts there is a succession of great mural precipices, showing on one single spot several hundred feet of strata; and how far such sections are from reaching the highest beds of the formation it is no easy matter to determine. The limestone is composed of two principal varieties, *common limestone* and *dolomite*; the former not to be distinguished in its mineral character from the great lower limestone of Westphalia and Belgium; the latter sometimes hard, crystalline, and marked by many beautiful impressions of corals—sometimes cellular and without any distinct traces of bedding—occasionally like a mass that is half brecciated and half concretionary, and sometimes quite earthy and incoherent, so as to resemble the pulverulent beds in our English formations of magnesian limestone. As a general rule (to which, however, there may be exceptions), the dolomites are

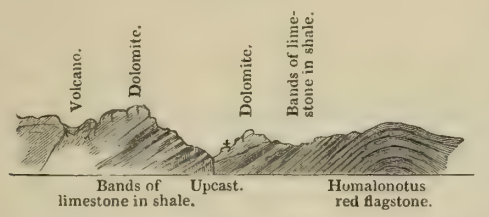
* See the Map, Pl. XXIV. and Section, Pl. XXIII. fig. 14.

in the upper part of the series, occupying the central portions of the several troughs; while on the outskirts of the formation we often see masses of unaltered and well-bedded limestone rising from beneath the great ridges of dolomite, and so forming the base of the troughs.

It is hardly possible to resist the impression that a great part of this formation has an altered structure; and when we remarked the numerous lofty cones of cellular and basaltic lava which studded many parts of the region—the great inverted cones breaking through the limestone, and containing cinders, scoria, and other indications of ancient volcanic vents—the great fissures in the Dolomites of Gerolstein, through which streams of lava and masses of scoria have mounted to the surface—above all, when we considered the wide-spread volcanic products which for several leagues cover up the whole eastern limits of the formation, we at first thought that we had before us the obvious causes of all that complexity of mineral structure which we have noticed.

Fig. 13.

Gerolstein.



Subsequent observations induced us to modify this opinion; for Dolomites occur at great distances from any of the modern volcanic vents. Moreover, these vents have produced a very small effect on the strike or inclination of the beds in any of the older formations*. Hence it is probable, that the chief mineralization of the Eifel limestone took place during some of those early periods of plutonic disturbance, during which the older strata of the Rhenish provinces were elevated and contorted. Before we quit this subject, we may remark, that the causes which mineralized the rocks of the Eifel may, perhaps, have driven off the carbonaceous matter they once contained; for we find among them none of those black beds which are so frequent in the lower limestones of Belgium and Westphalia.

Many of the fossils of the Eifel limestone are well known, among which are found certain Silurian species. These are however chiefly derived from the inferior shales, which we have not yet noticed; and it is important that the fossils of the upper and lower portions should be kept distinct. M. Beyrich of Berlin, whom we have before quoted, saw the importance of this distinction; and has, without any assumed hypothesis, and merely from the characters of the fossils, separated the limestones of Bensberg into two distinct formations. It is enough for us to observe in this place (referring for further evidence to our lists),—that the group of fossils in the Eifel limestone is Devonian—that we there find great masses containing *Strigocephalus Burtini*, and other well-known Westphalian species (which we never met with in the strata below the great Westphalian limestone)—and that nearly all the Silurian types which characterize the lower group are entirely wanting. We therefore place the great Eifel limestone on the parallel of the lower Westphalian and Belgian limestones, and consequently the lower part of the Devonian system. In this arrangement the conclusions derived from the sections and the groups of fossils are in harmony with one another.

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* As examples of what is stated in the text, we may instance the beautiful volcanic lakes near Daun and Gillenfeld, and the great crater of Bertrich. At these points of eruption the slate rocks of the country are very little mineralized, and have undergone no sensible change in their strike and dip.

Shales, Red Psammites, Schists, &c., under the Eifel limestone.
(h^1 of coloured Sections, Figs. 10, 12, 13, and 14, Pl. XXIII.)

The formation beneath the Eifel limestone is essentially the same, on whatever side we begin our examination.

We have first a series of shales more or less calcareous, alternating with the bands of limestone, and passing into the state of indurated marl. In its upper portion this group passes into, and blends with, the great overlying limestone. In its lower portion it begins to alternate with psammite and flagstone; the alternating shales lose their marly character, become more meagre and arenaceous, and are occasionally of a reddish tinge. The same colours are not unusual in the flagstones. Here and there the marly beds, along with courses of limestone, reappear at considerable depths in the descending section; but at length the formation passes into a vast deposit of flagstone and psammite, with bands of meagre shale and earthy schist repeated in many alternations.

The development of the series (though differing considerably from that of the corresponding deposits of Belgium) is almost exactly similar to that on the right bank of the Rhine under the lower Westphalian limestone; for there we have the same recurrence of thin calcareous bands, the same alternations and mineralogical characters, again and again repeated; so that one description might almost do for both. Near Daun, Prüm, Cronenburg, Münster-Eifel, and Euskirchen, there are clear sections, which prove that the strata underlie the great mass of limestone: and at these localities we found at least four species of *Orthis*, one of which approaches very closely to *Orthis orbicularis*, and another to *Orthis* or *Leptæna lata*, of the upper Silurian rocks. With these fossils are grouped certain Trilobites, which we cannot distinguish from published Silurian types, such as the *Calymene Blumenbachii*, *C. macrophthalma*, and two or three forms of *Homalonotus*, one of which resembles closely the *H. Knightii*. They are occasionally associated with the *Delthyris macroptera* and *D. microptera*, and with numerous *Tentaculites*. Thus the group we are describing is shown to be identical with that of the Lahn mouth, of Braubach, and of other places on the right bank of the Rhine, which we have considered as upper Silurian.

Notwithstanding therefore some difference of development, we are led (as we were on the other bank of the Rhine) to place this portion of our section in the upper part of the Silurian system. In this view, the upper marly shales can be regarded only as beds of passage, zoologically as well as mineralogically, between the Eifel limestone and the Silurian system. Now as many of the published Eifel fossils are derived from these marls, which contain an immense number of well-preserved organic remains, we need not wonder, on this explanation, at the occurrence of *so many well-known Silurian types among these published Eifel lists.*

The analogy between this and the corresponding group on the right bank of the

Rhine, is still further maintained by the numerous obscure vegetable impressions which are found in both of them; very seldom, however, in such a state as to give any hopes of determining their species.

Older Slates of the Moselle and the Rhine.—Formations of the Hundsrück and the Taunus, &c. (Map, Pl. XXIV. colour 8, Pl. XXIII. Sect. 9, colour *i.*)

We twice crossed the ridge between the north-eastern limits of the Eifel and the gorges of the Ahr, and we made three or four distinct traverses from the south-eastern ridges of the Eifel to the basin of the Moselle. From the Moselle we made traverses across the Hundsrück; and we endeavoured to connect our work together by an examination of the old rocks on the banks of the Moselle, and by repeated examinations of all the older rocks in the gorges of the Rhine between Bonn and Bingen. As a general result of these examinations, we may state, that we were not able, by any direct evidence of sections, to establish the order of superposition between the Eifel and the Hundsrück; in which respect we, however, encountered no greater difficulties than we had met with in the Ardennes and on the right bank of the Rhine. But in course of these traverses we found a series of great mineral masses following one another nearly in the order we have already described.

Under the great fossiliferous group containing the red shales and psammites is an enormous development of slaty flagstones, earthy schist, and shale of yellowish-grey, greenish-grey, and bluish-grey colours; sometimes blending themselves in structure with the upper group; sometimes passing into the condition of a coarse slate formation like the upper slates of the Ardennes,—not unusually presenting vegetable impressions, and occasionally bands marked with innumerable impressions of Encrinites, Corals, Orthidea, &c.

With these characters they appear in the gorges of the Lieser between Bleckhausen and Manderscheid, often in vertical positions, or thrown into the most fantastical contortions,—in the gorges that descend toward the Moselle, between Daun and Lutzerath,—in the magnificent sections of the Ahr—and on both banks of the Rhine between Bonn and Andernach. Similar rocks, and with the same general suite of fossils, follow both banks of the Rhine above Coblentz; and near the mouth of the Lahn they are shown to plunge under the limestones of the Devonian system described in the former part of this paper.

In the escarpments near Braubach and the mouth of the Lahn these rocks are, as already stated, extremely fossiliferous; the long-winged *Delthyris* (*Spirifer*, Goldfuss) and the *Homalonoti* being abundant, and the whole suite agreeing with that which we have already described, and considered as characteristic of the Silurian system in the Rhenish provinces.

Near Boppart, south of the mouth of the Lahn, the mineral system of the Rhine changes its character; not by any sudden transition nor in any well-marked order of superposition, but among numberless contortions, and by insensible gradations; so that above Oberwesel the whole has more the character of a slate formation than of an arenaceous flagstone. Beds of quartzite alternate, here and there, with fine masses of roofing-slate, which is obtained by a true transverse cleavage; and on both banks of the

Rhine, for about a mile above and below Caub, we found a slate-rock hardly to be distinguished from the *lower slates* of the Ardennes.

Below the fine slate zone of Caub, the rocks (though often with a true transverse slaty cleavage) are more arenaceous, pass here and there into masses of psammite, contain bands that are highly fossiliferous (*e.g.* the rocks on both sides of the Rhine for a mile or two above St. Goar, Lurleu, &c.), and therefore, mineralogically as well as zoologically, agree more nearly with the *upper slates* of the Ardennes.

The two traverses, by the gorges of the Lieser and the Ees, which descend from the Eifel to Wittlich and Lutzerath, present a similar sequence.

(1.) The fossiliferous marls, red slates, and psammites under the Eifel limestone.

(2.) Great masses of slaty flagstone, &c.

(3.) A great deposit of coarse arenaceous slate gradually passing, as we approach the banks of the Moselle, into the structure of a true slate formation. The upper part is most fossiliferous, and what is presumed (more on general analogy than on any evidence of sections) to be the lower part becomes less and less fossiliferous. Occasionally, however, the lower slates are intersected by certain bands, in which fossils are very numerous. Fine illustrations of the mineral structure of this third group, of its contortions, and its great development, are seen in the noble gorges of the Moselle, above and below Cochen; and in the fine transverse gorge of the Ees between Lutzerath and Alf.

On all these traverses, fossiliferous bands are found; and the many forms of *Orthis* belong to the same general group as those from the banks of the Rhine, and from the *upper slates* of Belgium and the Ardennes. Hence all the rocks which are beneath the fossiliferous marls at the base of the Eifel limestone, and are expanded through the districts we have last noticed, may be considered as a vast development of the Silurian system, without any subordinate bands of limestone, or distinct subordinate formations, to enable us to compare them with the subdivisions of that system in England. Hence also (with the exception of the more perfect slate rocks near Caub and on some parts of the right bank of the Moselle below Trèves, which may be provisionally assumed to represent the lower slates of the Ardennes (*système ardoisier inférieur*), we may regard the same series of rocks as representing, in their higher psammites, a portion of the lowest division of the *système anthraxifère* of Mons. D'Halloy and Professor Dumont; and in their lower arenaceous slates the *système ardoisier supérieur* of the same authors.

It remains for us to notice the chain of the Hundsrück and the Taunus, which are one continuous formation, only split asunder by the gorge of the Rhine immediately below Bingen. It appeared to us, after repeated examinations, that, assuming the slate rocks near Caub to be the oldest members of the Rhenish series, we had a regular ascending section, through arenaceous and earthy slates and flagstones, to the quartz rock and fine chloritic schist of the Hundsrück and the Taunus. We made five or six traverses through different gorges of these chains, with a view of making out the facts of superposition; and in every instance we arrived at the same conclusion. If we can trust the evidence of sections, these chains overlie the slaty rocks immediately skirting their north-western flanks.

The beautiful crystalline structure of these chains, their fine masses of white quartz rock, of chlorite slate, and micaceous slate, have led many authors to regard them as the oldest rocks of the Rhenish provinces; and this first error has been confirmed by a second, in which slaty cleavage has been mistaken for stratification.

Among the slate rocks of the Rhine the cleavage planes usually hang to the south-east, and keep their direction and inclination even among masses which are violently contorted. Hence any one assuming the cleavage planes for beds would not only form erroneous conclusions about the dip, but also most exaggerated notions of the thickness of the formations. Now in one or two places on the north flank of the Taunus, though the slate beds dip south-east, the inclination of the cleavage planes is reversed to the north-west: and hence, without very careful observation, we might be led to suppose that the quartzites of the chain rose from beneath the slates; which (if our views be correct) is a conclusion directly contrary to fact.

But it may be objected, that if the rocks of the Taunus and Hundsrück be members of an *ascending* section commencing from the old slates of Caub, we ought also to find corresponding rocks in the ascending sections on the other side of the old Rhenish slates; otherwise there must be a want of symmetry in the sections on the opposite sides of the central system. We admit the force of the objection; and we reply, that there are very fine quartzites in the ascending sections from the left bank of the Moselle towards the Eifel (for example in the Grunen-Wald north of Wittlich), and consequently that the ascending sections are not without mineralogical symmetry. Again, we found similar masses of crystalline quartzites associated with trappean rocks, on the right bank of the Rhine, and rising out at various points between Limburg and the Taunus*. If such masses have been produced by the action of igneous rocks on the more arenaceous slates, we have no right to look for their symmetrical arrangement on any corresponding sections. In short, we regard the structure of the Hundsrück and the Taunus as due to a long-continued action from below; which first lifting up their beds and twisting them, while in a softer state, into most violent contortions, gradually mineralized them and changed them into what they now are. Nor has the activity of these subterranean causes yet entirely ceased. The phænomena we have described may be regarded as the effects of their early and intense activity; while the hot springs of Wisbaden and the bubbling fountains of Schlangenbad, Langen-Schwalbach, and Nieder-Selters give indications of their feeble and expiring efforts in this mineralized region.

But our evidence does not end here; for we found Silurian fossils, from the quartzites of the Hundsrück, in the museum of Trèves†. We afterwards crossed to the eastern side of the chain, near Berkenfeld; and, through the kindness of M. Böcking, were directed to some quarries (immediately above Abentheur and Ringenberg) among fine vertical masses of quartz rock containing many organic

* Pl. XXIII. fig. 9.

† We were indebted to Professor Steininger for the knowledge of this fact, and for much interesting information respecting all the formations in the basin of the Moselle. He has since published a geological map of all the country between the Saar, the Moselle, and the Rhine.

remains. In these rocks were one or two species of *Orthis*, two large species of *Delthyris*, and the singular coral *Pleurodictyum problematicum*; which fossils also abound in the formations under the Eifel limestone; and are commonly found on the banks of the Ahr, the Rhine, and the Lahn, associated with the *Homalonoti*, and other characteristic Silurian types. Thus were our previous conclusions respecting the age of the mineral masses composing the Hundsrück and the Taunus, confirmed by the additional evidence of the fossils. It is indeed true that organic remains are very rare within the limits of these chains; but our only surprise was that any traces of organic forms should have been left among rocks so greatly mineralized*.

As general conclusions from this and the preceding part, we may state :—

1. That, considered on a broad scale, the successive natural groups of strata, and the successive natural groups of fossils are in approximate accordance.

2. That as the broad areas of the physical groups of strata are ill defined, so also are the boundaries of the fossil groups ill defined, and pass into one another.

3. That as there are no great mineralogical interruptions of the deposits, producing a discontinuity or want of conformity among the masses, so also there seems to be no want of continuity among the groups of the great Palæozoic series of animal forms. If the extreme terms be compared together, every object is dissimilar: but when the proximate groups are put side by side, there are many points of resemblance, and many of specific agreement. These conclusions are not offered as an hypothesis, but appear to us as legitimate inferences from the facts we have had before us during the compilation of this paper.

PART III.—*Structure and Formations of the Hartz.—Upper Franconia, &c.*

(Plate XXIII. Sect. 15, 16, 17 and 18.)

GENERAL STRUCTURE OF THE HARTZ.

Before we proceed to notice the formations of the chain of the Hartz, it seems expedient to give a brief sketch of its structure, which is, we believe, not well understood by the generality of British geologists. In English works, published not more than twenty years since, and professing to give some account of this region, the granite of the Brocken was placed in the geological centre; and all the stratified formations were delineated as mantling round it, and dipping from it in most regular order, beginning with the oldest slates at a high angle of inclination,

* See Pl. XXIII. fig. 9.

and ending with the newer Flötz rocks of the age of our green sand and chalk in a position almost horizontal.

These assumed facts were connected with the Wernerian theory, and offered in support of it. Hence they obtained a currency in this country which they very little deserved. In the year 1829, when we first crossed this chain, our surprise was indescribable when we found that the granite of the Brocken did not occupy any mineralogical centre—that it burst out at one side of the chain—that it very little affected the general strike of the adjacent beds—that the whole neighbouring series of secondary rocks was in a reversed position—and that all the "*flötz*" *rocks* on the N.E. side of the chain were highly inclined and often vertical. Errors like those above alluded to, have now been long exploded in the country which gave them birth.

As seen on a coloured physical map, the high lands of the Hartz put on the form of an irregular chain extending about N.W. and S.E. The greater part of these high lands are occupied by old slaty rocks; pierced, however, by innumerable masses of trap, porphyry, &c., and by two great bosses of granite, both of which break out on the eastern side of the chain, and come down almost close to the secondary formations*. It will also be seen by a glance of the eye at a geological map of Germany, that all these high lands are surrounded by secondary deposits (commencing with the red sandstone, zechstein, &c., and ending with the chalk), arranged with a near approach to symmetry. In one or two places on the north and south sides of the chain, and also near its western extremity, the old slate rocks (grauwacke) are immediately overlaid by a coal formation; but it is so imperfectly developed, so nearly linked with the *rotheliegendes*, or so much concealed and overlaid by porphyry, as hardly to constitute any feature on the map.

In making a traverse through almost any part of the old slate rocks of the Hartz, we find that their strike differs not much from the strike of the grauwacke of the Rhenish provinces, being on the average about N.E. by E. and S.W. by W. Hence the general strike of the beds by no means coincides with the longer axis of the high land of the Hartz; but, on the contrary, is more nearly at right angles to it. By this structure the subordinate features of the region are greatly modified: and from the top of the Brocken, or any of the other high elevations of the Hartz, one may trace a series of small subordinate ridges, defined nearly by the actual strike, and running transversely to the principal bearing of the chain.

On the contrary, the strike of the secondary system surrounding the Hartz (however modified here and there by local causes), is on the whole about N.W. and S.E. Hence it follows, that the direction of the chain of the Hartz, as laid down

* See the south-east end of the Section, Pl. XXIII. fig. 17.

on a physical map, is not defined by the strike of the mineral masses composing it, but by the general direction of the unconformable secondary strata which surround it. We have no example of such a chain in England.

In mineral structure the slate rocks of the Hartz agree generally with those of the Rhenish provinces. They agree also in their modifications of structure, and in their modes of association with trappean rocks: and in the contortions of their beds, and in the total inversion of enormous masses of them, they present the same difficulties in determining the true order of superposition from the mere evidence of vertical sections. But it is not merely from vast contortions and inversions, and the frequent intrusion of trappean rocks (like those described in the former pages of this paper), that the order of the formations is obscured. The great bosses of granite also play a most important part, both in modifying the structure of all the neighbouring rocks, and in producing a distinct order of dislocations. By the combination of all these disturbing causes, the chain of the Hartz has literally been broken into fragments, in such a manner that it would be almost impossible to give them any symmetrical arrangement out of which we might eliminate their true relations to one another*.

Lastly, in the Hartz the older strata are on every side cut off abruptly by the unconformable abutment of the secondary strata; so that we look in vain for any frontier, like that of Westphalia; where, after escaping from a sea of troubles, every formation rests in its proper order.

Before we go on to consider the evidence offered for the age of the formations of the Hartz, from analogies of structure and from fossils, we may briefly notice the principal igneous rocks which enter prominently into its structure.

They may be divided into four distinct classes.

1. *Trappean rocks that rise irregularly among the beds, and strike nearly with them.*—Some masses appear to have been protruded through the aqueous deposits: others are in more regularly stratified bands, passing sometimes into the state of *schaalstein*, and therefore apparently of a date contemporaneous with the slate rocks. From what we saw of these rocks, and still more from the specimens kindly exhibited to us by Professor Hausmann, they may be described in general terms by the name of greenstone, with many modifications. They are often ferruginous, and associated with deposits of iron ore near their junction with the regular strata; often very felspathic, containing here and there much Saussurite and small crystals of hypersthene, and rarely schiller-spar.

2. *Granite of the Brocken, the lower part of the valley of the Bode, &c.*—That this granite is newer than the rocks of the preceding class, is proved by the fact, that it cuts them all off and shoots its veins into them, or into the series of the rocks, of which they seem to form an integral part†. Neither can it admit of any

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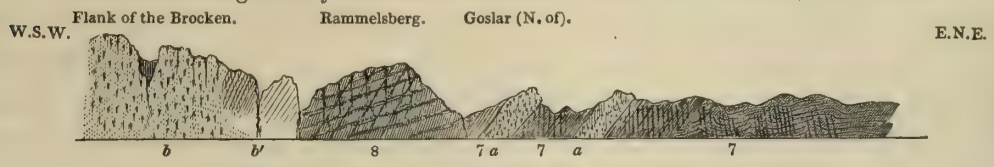
* This opinion has been expressed by Professor Hausmann and other German authors.

† By a precisely similar argument, we infer that the granite of Dartmoor is newer than the trappean rocks associated with the surrounding slates. On the contrary, in the Isle of Arran, the trap rocks are proved to be the newest, because they cut both through the secondary rocks and the granite.

doubt that it is a true eruptive rock: for in the upper part of the Ocker Thal, masses of grauwacke with organic remains are caught up in it*; and in ascending the Brocken we found several blocks of granite with imbedded splinters of grauwacke. Again, the slates nearly in contact with it, are often converted into hornstone, and the arenaceous grauwacke into quartz rock; and the junction specimens exhibit almost all those modifications of structure which are so well known in Devonshire and Cornwall. The granite of the Hartz, like that of Devonshire, has however produced but a very small effect on the general strike of the chain. Yet does it appear to have produced enormous derangements in the position of the subordinate masses: for all the older rocks, extending for many miles on the north side of the granite of the Brocken, are in a reversed position; and few of the masses near it show any conformity to its surface.—See Section 17. Pl. XXIII.

Fig. 14.

Inverted and fragmentary condition of the strata north of the Brocken, near Goslar.



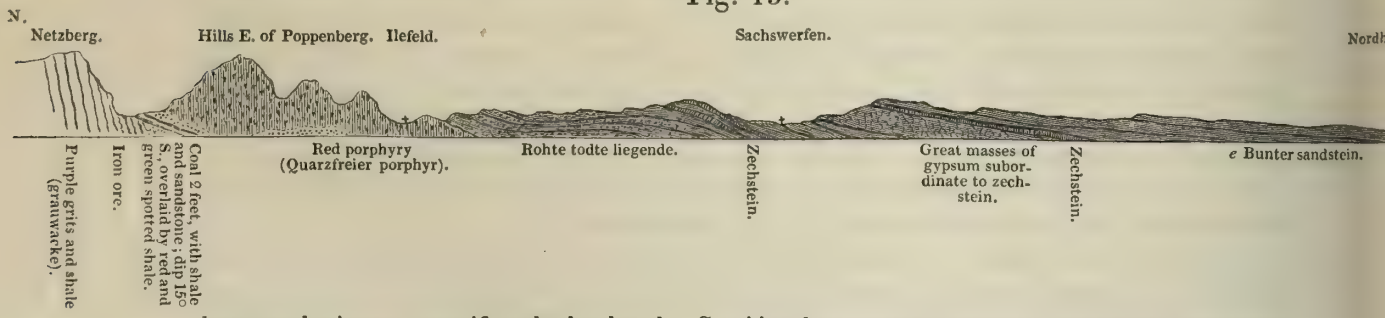
7. Devonian.
8. Silurian grauwacke.

a. Greenstones, &c., with Devonian slates.
b. Granite of the Brocken.
b′. altered grauwacke on the flanks of the Brocken.

3. *Quartziferous porphyry* (*Quarzführender Porphyr*).—It rises up in several bosses of considerable extent, in which respect it is unlike the *elvans* of Cornwall. Yet does it occasionally send out dykes into the neighbouring strata; and in mineral structure it has close analogies with the commonest varieties of Cornish elvan. The specimens of this rock, which we saw near Stolberg, contained a great deal of pinite. These trappean masses are considered, we believe correctly, as newer than the granite, in which respect they present another analogy with the Cornish *elvans*.

4. *Newer trappean rocks, overlying and alternating with coal shale, red sandstone* (*rothliegendes*).—These are described in the German maps of the Hartz under the general name of *Quarzfreier Porphyr*. They are of very varied structure, passing through every shade, from red felspar rock to black augitic trap and basalt. The accompanying woodcut will explain their general relations, both to the newer and older stratified masses, as seen in some remarkable sections near Ilefeld, on the south side of the chain, where

Fig. 15.



these porphyries are magnificently developed. Considered as a whole they are undoubtedly true eruptive rocks; yet are they most intimately associated with the red sandstone and the thin carboniferous

* M. Zincken showed us some specimens of granite in which had been caught up fragments of *calcareous* rocks with *organic remains*; but we do not remember from what part of the Hartz he had obtained them.

beds: and in one or two places which we examined, the beds of meagre shale and reddish grits, though containing coal plants and alternating with thin bands of coal, seemed in a great measure to be made up of recomposed trap.

This *Quarzfreier Porphyr* is therefore unquestionably of a newer date than most of the trappean masses above alluded to; and it is regarded by Von Buch and some German geologists of high authority as a manifestation of those subterranean forces which produced the last great elevation of the Hartz, and gave the present strike and impress to the secondary system by which the chain is surrounded. We were disposed to regard the granite as the indication of the great moving power in elevating the chain; and we thought our views confirmed by the complete inversion, not merely of the older rocks, but of the whole secondary series (including red sandstone, muschelkalk, greensand and chalk), in the neighbourhood of Goslar. But the subject is one of the greatest complexity, and we do not venture to oppose our opinions to those of Von Buch, Hausmann, or any of the geologists who have described the igneous rocks of the north of Germany in such admirable detail. One thing at least is certain, that the formations of the Hartz must have undergone many movements; and the position of the surrounding strata seems to prove that the whole chain must have had a great movement *en masse*, since the period of the secondary deposits (see Pl. XXIII. fig. 17).

It is demonstrated, by the sections, that the strike and flexures of the grauwacke were effected *before* the existence of the overlying coal and *rothliegendes*. On the contrary, we have shown that in Belgium and Westphalia the strike and flexures of the grauwacke are propagated into the coal formation. Are we then to believe that the causes which produced the peculiar physical impress on the vast series of strata in the Rhenish provinces, belonged to a different period from that during which the strike and contortions of the Hartz were effected? We answer this question in the negative, believing that the older rocks of the Hartz and the Rhenish provinces compose but one system, made up of similar component parts, which have been similarly acted on and dislocated at the same periods of time: and we escape from this apparent contradiction by supposing that the coal measures of Westphalia and Belgium are an older part of the series than the coal measures of the Hartz. Indeed we regard the coal-beds on the flanks of the Hartz as the very highest part of the carboniferous series, just where it alternates with and passes into the bottom beds of the new red system; and by no means as representing the whole carboniferous system. On this view there is no contradiction in our previous conclusions*.

* We consider the coal-beds associated with the *rothliegendes* of the Hartz to represent the thin bands of upper coal which alternate with the bottom beds of the new red sandstone series in Shropshire, Staffordshire, Worcestershire and Warwickshire. Between the *rothliegendes* and the *old red sandstone* of

Age of the Sedimentary Deposits of the Hartz.

Having thus considered the general structure of the Hartz, we next come to consider the age of its sedimentary deposits. That in their structure, their strike, their accidents of position, and their fossils, they present the closest analogies to the rocks of the Rhenish provinces, is easily shown; but in explaining the relations of the subordinate formations to one another, we are, for reasons already stated, involved in the greatest difficulties. There are, however, among the fragmentary masses of the Hartz a few sections which give a pretty clear indication of natural groups, especially when put in comparison with the still clearer sections of Westphalia. We will first shortly notice one or two sections on the north-western side of the Brocken.

Section from Osterode to Clausthal.

In ascending from Osterode to Clausthal we crossed one of the great spurs of the Hartz, composed of alternating beds of grit, psammite and shale, striking about N.E. and S.W., and dipping at a great angle, sometimes N.W. and sometimes S.E., the latter dip being most prevalent. The sandstones were generally in thin hard irregular beds, from one to four inches in thickness; more rarely in well-defined beds from six inches to two feet in thickness; their colours were grey, greenish-grey, mottled, purple and reddish; and sometimes almost black, from the carbonaceous stains diffused through them. The alternating shales were generally thin-bedded, of bluish grey and purple colours, and had, here and there, much carbonaceous matter between their laminæ. During the traverse we hardly saw a rock we might not match among the culm-measures of Devon; and here also, as in Devon, we found an indefinite number of impressions of small reeds and grass-like plants. The rocks above described are broken through and interfered with by masses of greenstone, amygdaloid, &c., ranging nearly parallel to the prevailing strike; and the whole system is continued till it is lost under the alluvial covering near Clausthal.

Section from Clausthal to Gründ.—(Pl. XXIII. fig. 18.)

In making this traverse by the mine-works, we first crossed a series of beds dipping S.E. at a considerable angle, but not without the interruption of many great irregular flexures. They contained a few impressions of plants, and could not be mineralogically distinguished from many parts of the culm-mea-

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England there is no analogy whatsoever; though such was formerly supposed, and might seem indeed to be implied in some of the sections of Hoffmann. Though the carboniferous beds on the southern flanks of the Hartz may seem to confirm the opinion, that the coal formation is but an accidental deposit subordinate to the red sandstone (*un accident dans le grès rouge*), they do not represent the great carboniferous systems of Westphalia and Belgium; and still less the carboniferous system of Great Britain. In further confirmation of this opinion, we may state, that true coal plants and thin carbonaceous laminæ occur in great abundance in the lower division of the new red sandstone, between the magnesian limestone and the rich coal formation of Whitehaven, and also in the same formation near Birmingham (see Silur. Syst., p. 55, and note, p. 56). We have only to suppose these plants and carbonaceous bands more largely developed, so as to form beds of coal, and we shall then have an upper division of the coal formation precisely in the position of that of the Hartz.

sures of Devon. Near the Frankenhamer Hütte are thick beds of sandstone with fine Calamites and other vegetable impressions. Some of the great masses of sandstone are separated into rhombohedral blocks by a double set of joints,—one set (*strike-joints*) ranging with the beds, though generally dipping to an opposite point of the compass; the other set (*dip-joints*) ranging nearly N.W. and S.E.

The colours of these sandstones are various—yellowish grey, brown, greenish grey, smoke grey, with small quartz veins, &c. Small spots of *kaolin* are diffused through some of them; and among them, not unusually, are seen numberless bright granules of greasy quartz. Beds like these, alternate with slightly micaceous flagstones, and thick beds of dark carbonaceous shale.

Further down the valley (below the smelting-houses) are beds of a very coarse grit, with granules of greasy quartz as large as peas, like many varieties of millstone grit. These rocks rise into the hills towards Gründ, in the direction of which we continued our traverse through a dense forest, which greatly obscured the section.

We then crossed some beds of dark, indurated, carbonaceous shale, from beneath which rises a very remarkable mass of limestone. Its dip is extremely obscure, some beds being greatly mineralized, broken, fissured, and penetrated by veins of sulphate of barytes; but as the principal mass ranges through the dense forest in a direction about N.N.E., we presume that it represents the true strike of the beds. This limestone is generally light-coloured and highly crystalline; and the veins and hollows on its flanks are in some places much charged with iron ore. The whole mass of it, especially in the Hübigenstein (which rises into bare pyramidal peaks in figure giving a minature resemblance of some of the dolomites of the Alps), is much charged with corals, and in some of the earthy partings of the more crystalline beds or masses are numerous fossil shells. The corals, as a suite, are identical with those of the great limestone of Westphalia and the Eifel. Among the shells are

Spirifer striatulus, so common in the Devonian strata of the Boulonnais.

——— *glaber*.

Terebratula concentrica (V. Buch), } both good Devonian species.
Terebratula prisca, }

Goniatites discors, the same species as at Oberscheld in Nassau.

Among the shells enumerated by M. Zinchen from this locality were *Cardium alæforme* (Sowerby), and *Terebratula elongata* (Schlotheim).

On the west side of Gründ the section is almost entirely concealed; and the whole series of older rocks is soon afterwards cut off by the terrace of the overlying *zechstein*.

From the whole evidence, we have no doubt that the calcareous mass of Gründ is a true Devonian limestone; and that the overlying beds are the equivalents of those parts of the Westphalian sections which extend from the great limestone to the base of the coal-measures.

We afterwards made a complete traverse from Clausthal by the line of the Innerste; and though we were unable to make any connected section to determine the order of the successive mineral masses, we saw nothing to invalidate our previous conclusion.

To the west of the river gorge is a mass of limestone like that of Gründ (which, however, we did not examine); and in descending the gorge (below the point where we had left it in the previous traverse) we met, first with black carbonaceous shales and grey sandstones; then with grits, shales and psammites, in some places contorted and greatly mineralized. Afterwards, near Lautenthal, we passed singularly contorted masses of *Kiesel Schiefer*, resembling the rocks before described north of Meschede*; and we afterwards saw specimens of *Posidonia* obtained from these localities, though we were not fortunate enough to meet with that fossil during our traverse. Still further down the river gorge we met with quarries of a slightly calcareous slate, which we supposed to represent the shales between the Devonian limestone and

* *Antè*, p. 232.

the *kiesel schiefer*. The structure of the rock was very interesting. The component beds were greatly contorted, and intersected by a fine, highly inclined, transverse, slaty cleavage inclining to the S.E. A number of regular horizontal joints gave a false appearance of horizontal bedding, and these were intersected by another system of *dip-joints*, with seams of carbonate of lime. The lower part of the valley (where the river emerges into the plains of keuper, muschelkalk, &c.,) gave us no additional information.

Section (N.N.W. and S.S.E.) *from the Hills a few miles north of Goslar, through Rammelsberg to the Granite of Ocker Thal.*

The woodcut, Fig. 14, given in p. 286 will be sufficient to convey a general notion of the actual position of the mineral masses in this section.

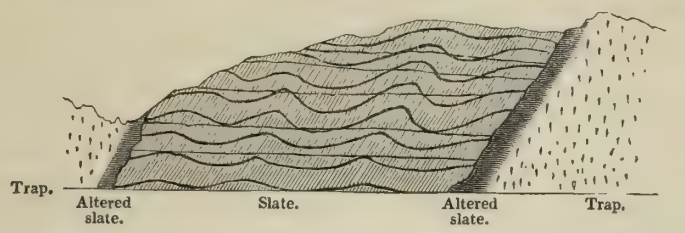
1. We have first a series of dark earthy slates and psammites much contorted.

2. Then a series of hard dark glossy roofing slates, interrupted by great alternating parallel ridges of trap (*e.g.* in Grana Thal, Nordberg, and Steinberg). These schists have a fine slaty cleavage, which hangs steadily to the S.E. at a great angle. Some of the slates, alternating with the thick bands of trap, are, however, highly contorted, and of very complicated mineral structure, as is shown in the accompanying woodcut.

Fig. 16.

Slate-quarries of Nordberg, near Goslar.

The undulating lines of this figure indicate the bedding; the inclined lines the cleavage; and the horizontal lines the peculiar joints or floors.



The true beds of slate are marked by a contorted *stripe*. The sides near the trap are altered and indurated; the slaty cleavage is very well defined, dipping at a high angle to the S.E.; and the whole mass is separated into well-marked tabular masses by horizontal joints.

3. The preceding series is overlaid by soft earthy slates (of the gorge above Goslar), which, in their turn, are overlaid by the series of the Rammelsberg. The beds here continue on the whole to hang to S.E., but not at a great angle; and there are several small undulations, by which the dips are changed and sometimes reversed. Many of the beds are, however, intersected by planes of cleavage, inclined at a great angle toward the south-east, which sometimes convey a false notion both of the bedding and dip. Near the top of the hill we have the following *apparently ascending* section:—

(1.) Hard grey well-bedded sandstone.
(2.) Hard flagstone, with bands of indurated slate.
(3.) Chert or quartz rock, broken into small irregular fragments by joints coated with ferruginous stains.
(4.) Ragged arenaceous slates.
(5.) Hard quartzose arenaceous beds rising to the top of the hill. The preceding beds contain a few fossils.

Following the line of section to the southern side of the mountain, we found the arenaceous system

(grits, psammites, grauwacke, grauwacke-slate, &c.) alternating with bands of rotten-stone, containing very numerous fossils, among which we collected *Trilobites*, *Tentaculites*, one or two species of *Delthyris*; in short, the same group of fossils which characterizes the Silurian grauwacke of the Rhine.

4. Similar masses may be followed along the same line over another series of ridges into the Ocker Thal, where they sometimes appear to abut against, and sometimes even to dip under, the granite, at the most northern prolongation of the Brocken. In that valley all the phænomena are of the highest interest. The relations of the rocks are shown in the deep clefts through which the Ocker finds its way. The granite rises into noble pyramidal forms, and the slates are mineralized, veined, broken up, and thrown into vast disjointed masses; and had we no other evidence than the great bare sections of the Ocker Thal, we should conclude that the strata composing the mountains on its north side had been elevated through an angle of more than 90°, and thrown into a reversed position.

We believe, indeed, that all the beds of the preceding section are in a reversed position; that the beds extending from Rammelsberg to the granite are the *oldest*, and that the slate masses north of Goslar are the *newest*, portions of the section (see the woodcut, p. 286). We adopt this supposition because it best explains the relations of the mineral masses, and the distribution of the fossils; and there is in it nothing improbable, considering the vast derangements in the neighbouring country.

For example, we may take a section from the low secondary country, a few miles north-east of the Ocker Thal, to the granite, and find the following series:—

(1.) Tertiary rocks and chalk, in their natural position, and dipping from the chain of the Hartz.
(2.) Greensand greatly contorted, and on one side dipping *towards* the chain of the Hartz. Beyond these disturbed beds all the formations dip *towards* the central mass of the Hartz, and therefore appear to form *an ascending section.*
(3.) Jura limestone.
(4.) Lias overlying the preceding.
(5.) Keuper overlying the lias.
(6.) Muschelkalk and bunter sandstein overlying the keuper.
(7.) Slaty rocks, having on the whole nearly the same dip with the preceding, and *appearing* to overlie them.
(8.) Granite, abutting against, and in some places appearing to overlie, the grauwacke.

Now it is absolutely certain that the greater part of this section (extending over many miles) is in a reversed position. There is, therefore, no violation of analogy in the supposition we adopted respecting the older rocks in our previous section.

Among the fossils of the Rammelsberg range are two species of *Homalonotus*, one not to be distinguished from a species found at Altenahr: also *Tentaculites*, large crinoidal rings, several species of *Orthis*, and two of *Spirifer*, all undistinguishable from species found in the Silurian grauwacke of the Rhenish provinces above described. On the contrary, the small *Orthoceratites* and flattened *Goniatites* in the black slates N.W. of Goslar appear to us to be Devonian. Moreover, this supposition agrees

better with the distribution of the great mineral masses towards Lautenthal. And hence we conclude that the whole section (woodcut, p. 286) is in a reversed position*.

In the previous details we have endeavoured to give some notion of the formations occupying a triangular area extending from the northern extremity of the chain to a line drawn from Osterode to the Ocker Thal. This we regard as one of the fragmentary masses of the Hartz; and according to our interpretation of them, the formations are composed of Silurian and Devonian rocks, ascending (in the highest parts of the section) to the base of the carboniferous system.

Section from the Granite of the Brocken through the Limestone of Elbingerode to the Granite of the Rosstrappe on the Bode.—(Pl. XXIII. f. 17.)

It forms no part of our object to describe the granite of the Brocken; neither can we dwell on the bristling peaks of granite that fringe the cleft, a thousand feet in depth, through which the Bode escapes from the mid region of the Hartz into the plains of Quedlinburg. Still less are we called upon to describe the secondary rocks which appear at the south-eastern extremity of our section (Pl. XXIII. f. 17). They are placed there only for the purpose of giving a general notion of the great movements to which these formations have been subjected. Their general position is nearly vertical; and had a similar section been made from the Brocken to the country north of Neustadt, the same secondary series would have been seen in a completely reversed order, and appearing, as we have before stated, to dip under the old rocks of the central Hartz.

The rocks nearly in contact with the granite at both ends of the section are indurated and greatly altered in structure, and partially penetrated by granitic veins. A remarkable saline spring nearly marks the junction of the slaty rocks and the granite on the south side of the Rosstrappe.

We mounted to the line of our section from Wernigerode, through beds of grauwacke interrupted by many points and ridges of trap. Near the top of the ascent (a little to the north of Elbingerode) we crossed some courses of dark-coloured limestone with white veins, and associated with projecting bosses of trap. To the N.W. of this point are bands of ferriferous limestone alternating with beds of porphyry,

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* The following fossils, from the neighbourhood of Goslar, are in the printed lists communicated to us by M. Zincken:—

Goniatites primordialis, *Buch* and *Schloth.*	Delthyris macroptera, *Goldf.*
——— simplex, *Buch.*	——— lævicosta, *Goldf.*
Bellerophon nodulosus, *Goldf.*	Cyathocrinites pinnatus, *Goldf.*
Pecten Oceani, *Goldf.*	Favosites polymorpha, *Goldf.*
Calceola sandalina, *Lam.*	

It is, however, obvious that in this list the fossils of the upper and lower parts of our section are confounded together.

the whole mass dipping at a great angle towards the Brocken. At Bücker Berg the iron ore forms an enormous mass, resembling some of the deposits near Dillenburg; but it still preserves a rude conformity to the prevailing strike and dip of the beds.

Over the preceding series are dark slates and *kiesel schiefer*; and, if we are not misinformed, Posidonia schist has been discovered on the same line, though in our rapid examination we were not fortunate enough to find it. Close to the granite the beds are entirely mineralized; and in most of the geological maps are represented by a distinct colour under the names of Trap, Diorite, Hornfels, &c. From under the preceding series rises the dark bluish grey coralline limestone of Elbingerode, which in its mineral character, as well as in its fossils, is the perfect counterpart of the great limestone of Westphalia. (See the section, Pl. XXIII. fig. 17.)

Taking then this limestone as a centre, we have an ascending section towards the Brocken, agreeing (not merely in its general relations but even in its mineral accidents) with many of the ascending sections, from the great limestone of Westphalia to the base of the carboniferous system.

We believe that the great limestone of Elbingerode forms a kind of irregular dome, throwing off nearly the same succession of beds to the N.W. and to the S.E. It undergoes many changes of colour and structure, especially in the vicinity of the igneous rocks by which it is pierced, when it sometimes becomes very hard and crystalline, and nearly loses all traces of regular stratification.

We, in the first instance, continued the section to the S.E. along the Bode, by Rubiland and Böhman's Höhle, and thence down to Schiefer Thal; and the phænomena were in the following order. A little below Elbingerode the limestone is cut through by a great band or dyke of porphyry; beyond which it becomes lighter coloured, obscurely stratified, and more jointed. Again, a large trappean mass interrupts the limestone; some of it passes into a nearly compact feldspathic rock, other parts are dark and almost basaltiform; but its structure is very variable. This mass may be regarded as the centre of elevation; for beyond it the dip of the limestone is reversed to the south-east. The same dip is continued in a greater succession of beds of subcrystalline limestone, through Rubiland and Böhman's Höhle; and a little below the latter place a mass of porphyritic trap has broken through the limestone and brought up some beds of the inferior grauwacke*.

Beyond this spot are some beds of crystalline limestone quarried for marble, not far from which are masses of iron ore. This part of the series is followed by a great succession of stratified trappean rocks, some of which are extremely cellular (*blatterstein*); others pass into green and thinly laminated *schaalstein*; some resemble earthy regenerated beds, while others are more crystalline, and pass into a true porphyry with a compact base. These singular rocks are continued into a part of Schiefer Thal considerably below the village of Neuburg, and are then replaced by dark glossy slates containing a few calcareous veins.

Several of these bands of slate alternate with the *schaalsteins* and other stratified trappean rocks, the whole series preserving the same strike and south-easterly dip.

To the section just described many of the ascending sections of Westphalia and Nassau, which commence with the great limestone and rise to the base of the carboniferous series, present the closest analogies. Respecting the age of the contorted and altered slates which extend to the granite of the Rosstrappe, we possess no materials for offering any exact opinion; and it is possible that among them

* We have endeavoured to convey a correct general notion of this succession in our section (Pl. XXIII. fig. 17); but it is obviously impossible on such a scale to attempt any delineation of the more minute details; nor indeed was our examination of the country of such a kind as to enable us to give them.

some beds may have been brought up, by the action of the granite, of an older date than any of those above described in the traverse from Elbingerode.

From the lower gorges of the Bode we returned to the south-eastern edge of the great calcareous dome near Hüttenrode. The *ascending section* is there more clear than on the banks of the Bode, being less modified and interrupted by the trappean slates. It is nearly as follows:—

(1.) Great limestone.
(2.) Four or five bands of limestone, alternating with masses of brown and some red iron ores.
(3.) Stratified slaty trappean rocks (*schaalstein*, &c.), alternating with some dark slates.
(4.) Dark-coloured slates, &c.

Beyond Hüttenrode the bands of ironstone recede towards the north, bending round with the dome of limestone; and along the new *chaussée*, from Hüttenrode to Blankenburg, both black slate and *kiesel schiefer* are seen distinctly to overlie the limestone series. The analogy with the Westphalian sections (*supra*, p. 229 *et seq.*) is therefore still more complete than we had shown it to be in either of the two preceding traverses.

Lastly, we descended to Blankenburg among schists, psammites, and masses of eruptive trap, probably of an older date than any of the rocks in the above section.

Two lines drawn, in the strike of the beds, across the chain, one through the granite of the Brocken, the other through the granite of the Rosstrappe, will cut off a great central area. Within this area, are the rocks last described, and on the north-eastern side of it we have shown that the Devonian system is widely expanded. The beds on the south-western side of the central area we did not examine; but, from general analogy, and from the information we obtained respecting them, we believe that none of them are older than the Silurian grauwacke of the Rhenish provinces.

South-eastern Extremity of the Hartz.

A line drawn along the strike of the beds a little north of Ballenstadt and Stollberg, cuts off the south-eastern extremity of the Hartz, which it remains for us very briefly to notice.

We made one excursion from Ballenstadt to Magdesprung, and thence down the whole gorge of the Selke. We found a dark limestone, with white veins, alternating with schists and psammites near the *Fürst-weg*, about three miles from Ballenstadt; but we were not fortunate enough to find any fossils associated with it. After descending among bosses of trap to Magdesprung, we found beds of hard glossy clay slate, with a true transverse cleavage, crossing the Selke below the village, and dipping about S.E. Further down the banks of the river the slates

became calcareous, and a dark-coloured limestone (with the same strike and dip) crossed the valley. We found a few encrinital stems in it, but no good characteristic fossils. Further in the descending traverse were many masses of hard grauwacke of various colours, generally grey or greenish grey, and sometimes altered, extremely jointed, and interrupted by projecting masses of trap.

After several undulations near the mouth of the gorge the prevailing dip is reversed to the N.W.; and the older rocks are overlaid unconformably by red conglomerate, coal beds, red sandstone, &c., which dip, from the upturned edges of the slaty rocks, towards the low country. The coal has been worked extensively all the way from Meisdorf to Ballenstadt, and is undoubtedly subordinate to the red conglomerates and red sandstones associated with it. Its relations are very clear, not being obscured, as at Ilefeld (*antè*, p. 286), by masses of eruptive porphyry.

From the structure of the slate beds on the Selke, the rarity of organic remains, and the absence of carbonaceous stains and impressions of plants, we concluded that the system of rocks on this traverse belonged to the older or Silurian grauwacke of the Hartz.

We afterwards made a complete traverse of the chain by Ballenstadt, Magdesprung, Hartzgerode, and Stolberg, and were accompanied by Mons. Zincken to the Schnechenberg (near Hartzgerode), where a dome-shaped concretionary mass of limestone, fifty or sixty feet thick, appears among the slates. It is dark grey and bluish grey, with many curved contemporaneous veins. The bottom of it passes into the slates; and there are foliated slaty portions through its mass; but some of the larger subordinate concretionary masses will take a polish, and are used for marble. We remarked in it some fragments of encrinital stems, and one or two obscure traces of small bivalves; but the fossils are very rare.

It appears, therefore, that between Ballenstadt and Hartzgerode there are three or four independent concretionary masses of limestone, nearly on the same line of strike, but with relations far too obscure to offer any good base line for the sections in this district of the Hartz. We have the authority of Mons. Zincken for asserting, that to the S. and S.E. of this line no limestone has yet been discovered, and that the prevailing rocks have the same general characters, and probably belong to the same age with those we remarked in the gorge of the Selke*.

* Since we left the country M. Zincken has forwarded to us drawings of Trilobites from this region, which induce us to consider the rocks of this southern end of the Hartz as a part (probably the lower) of the Silurian system.

Stratified Rocks extending from the Thuringerwald, through Upper Franconia, to the Fichtelgebirge.

It formed no part of our original plan to examine the formations between the Thuringerwald and the Fichtelgebirge. But having decided to visit the calcareous deposits on the north flank of the Fichtelgebirge, we thought it most instructive to approach them by a long traverse from the Thuringerwald through all the older rocks of Upper Franconia.

We entered the country from Weimar by the line of the Saal; and passing over the successive escarpments of the muschelkalk, bunter sandstein and zechstein (the last of which in several places rests unconformably on the grauwacke without the intervention of any conglomerate), we made our first traverse among the older rocks beyond Schwartzburg by the beautiful gorges of the river Schwartza. We found the slate rocks dipping N.W.; they alternate with quartzites, and are intersected by *dip-joints* and *strike-joints*—the latter generally inclining to a point opposite to the dip of the beds. The cleavage is irregular—sometimes striking with the beds, but at different angles of inclination—and sometimes transverse to the beds, and nearly parallel to the *dip-joints*. Farther up the gorge are some contortions; after which the dip is reversed to the S.E. There are some good slate quarries where this dip prevails, though the planes of slaty cleavage incline at a great angle to the N.W. In nearly the whole gorge, up to the castle of Schwartzburg, the induration of the rocks, the well-defined slaty cleavages transverse to the true beds, the alternations of quartzites with the roofing slates, and the chloritic tinge of many of the larger masses, reminded us of the lower roofing slates of Westmorland and Cumberland (Cambrian).

About three or four miles up the valley, at Dachnitz, we found beds of half brecciated and half concretionary marble dipping S.E. These beds alternate with bands of slate, exhibiting a transverse cleavage, which does not affect the limestone; and the whole system is underlaid by black pyritous shales, containing many ferruginous concretions.

From Dachnitz we made a traverse on foot through mountain forests to Saalfeld. In one of the gorges (near the last-named place), through which passes the great road to Coburg, we found a limestone similar to that of Dachnitz, and associated in like manner with highly pyritous black shales used in the manufactory of alum.

Again, about two miles above Saalfeld, we examined a fine cliff on the right bank of the river, composed of a reddish flagstone, some parts of which were studded with minute calcareous concretions. The calcareous matter was not sufficiently abundant to form any beds of limestone; but the general mode of aggregation was analogous to that in the limestone quarries above mentioned. These

calcareous flagstones are of great thickness, and their prevailing dip is N.W., though they exhibit two sets of great flexures; and they are overlaid by fine tabular masses of zechstein without the intervention of any red conglomerate. Like all the other calcareous bands in this region, they are underlaid by black pyritous shales used in the manufactory of vitriol.

In the absence of organic remains, of which we did not find a trace (with the exception of one or two obscure indications of crinoidal stems), it is in vain for us to offer any definite opinion respecting the age of the series of rocks above described. When on the spot, we thought them, as a whole, older than the grauwacke of the Hartz; and we are now disposed to class them provisionally with the upper slates of the Ardennes (*système ardoisier supérieur* of Dumont). Respecting the overlying deposits, we may remark, that the cliffs of zechstein or magnesian limestone near Saalfeld are very striking, and that the formation there maintains the same great development as on the southern and south-eastern edges of the Hartz.

It would be useless for us to attempt to offer a detailed section of the beds observed in an *oblique* traverse, which we made by the great road from Saalfeld to Coburg; but the following memorandums may serve to convey some notion of the structure of this mountainous country.

(1.) At the first hill the dip was N. and N.N.E., with many irregular undulations.

(2.) At the second hill the dip was S.S.E. and S.S.W., and after various undulations the beds for some way were nearly horizontal. The prevailing rock is a hard close-grained grauwacke, passing into flagstone and slate, and sometimes into a hard quartzite. Many of the beds exhibited rude irregular concretions and ferruginous joints.

(3.) At Schmeidefeldt are deposits of iron ore in nearly vertical masses, striking N.E. by N., and S.W. by S. with the regular beds.

(4.) At Wallendorf are quartzose flagstones and red close-grained grits, like those of the Longmynd and some of the older British slates.

(5.) Beyond this place we found red arenaceous slates, and some hard greenish slates brought up in long undulations; but on the whole the dip to the S.E. or S.S.E. seems to prevail.

6. At Hersach the whole series is carried under some black aluminous and pyritous slates containing some subordinate masses of limestone. These limestones offer analogies with the limestones on the Saal; and contain a few crinoidal stems, but no other fossils that we could observe.

7. Beyond this place a change occurs in mineral structure—the hard greenish slates and bands of quartzite disappear; the beds become more earthy and arenaceous, resembling many of the rocks of the Rhenish provinces described in the early part of this paper.

8. Finally, the old rocks descend into the low hills at Sonnenberg, where they pass under the terrace of the new red sandstone*.

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* The descending order through *keuper*, *muschelkalk* and *bunter sandstein* (*trias*) is very symmetrically displayed on the sides of the slate hills of Coburg, through which we passed.

We saw no reason for placing these rocks in a class different from that of the rocks between the Schwartza and the Saal near Saalfeld. We are informed, that rocks, of nearly similar structure, range (with countless undulations and numerous interruptions from ridges of trap) many miles further towards the south; and that a few Silurian fossils and a few impressions of plants have been found in some of their subordinate beds; in which case they may be classed with the fossiliferous grauwacke of the Rhine. Without venturing an opinion on a point we were prevented from examining personally, we may remark that the whole series appears to be overlaid by the highly fossiliferous limestones and slates south of Hof in the Ober Frankenwald, which we next proceed to notice.

Sections of Hof, Elbersreuth, &c. (Plate XXIII. Sections 15 and 16.)

Having been furnished with instructions by Count Münster (whose unceasing labours and numerous works have thrown so much light on the palæontology of his country), we went from Baireuth to Hof; and during one or two short excursions from the latter place, collected together the facts represented in the section, Pl. XXIII. fig. 15.

On our way to Hof we crossed the escarpments of the muschelkalk and bunter sandstein, and then entered on a defile among the older rocks at Bernich, from which place we skirted the north flank of the Fichtelgebirge, among crystalline slates and other altered deposits associated with granite. In the early part of this traverse we found a boss of porphyry, throwing off a mass of crystalline marble on one side, and of a thin-bedded encrinite limestone, alternating with *schaalstein*, on the other. The same series of beds was overlaid, near Latzüruck, by *schaalstein* passing into slaty porphyry.

We have no materials for marking the age of this limestone; and we mention these facts only to show the near analogies of structure exhibited in this country and in certain parts of the Hartz and of Nassau. We believe, however, that these analogies are presented by rocks nearly of the same age: for, if we mistake not, some of the crystalline and calcareous masses on the north flank of the Fichtelgebirge are only metamorphic portions of a series of rocks we are about to describe in the accompanying section (Pl. XXIII. fig. 15).

1. The highest calcareous bands of our section occur at Trogonau; but they also break out at Regnitz, Irsau, and Würlitz. They are composed of dark blue, uneven beds of limestone, with white contemporaneous veins, dipping with some irregularity, but on the whole to the S.E. at an angle of 25° or 30°. They are overlaid by a dark shale, which is lost under the black shale and alluvium of the plains below. In structure this limestone cannot be distinguished from the most common form of mountain limestone: and it contains *Actinocrinites*, *Rhodocrinites verus*, *Amplexus coralloides* (Sow.), several very large *Productæ* (one of which is spined), *Euomphali*, and several mountain limestone corals, &c. We therefore think its identification with the mountain limestone (as determined by Count Münster) quite unequivocal.

2. The limestone is underlaid by earthy, dark-coloured schist, very ill exposed, over which we made a traverse of one or two miles to Gattendorf.

3. At Gattendorf rises a lower limestone composed of dark grey, and in some places of reddish grey

beds, dipping irregularly, but on the whole about S.W. at an angle of 30°. Most of the beds are subcrystalline and much jointed; but some of them pass into a more compact state, and are much quarried for ornamental marbles. They contain many specimens of Orthoceratites, among which are *O. speciosus*, *O. regularis*, *O. maximus*, together with *Clymenia undulata*, *Clymenia lata*, *Goniatites undulosus*, *&c.*

4. These beds are underlaid by earthy schists without fossils; and by great masses of trap which break out on the banks of the river on the side of Hof.

5. On the N.W. of Hof is a great mass of marble, partly of a concretionary structure, and partly brecciated, resembling the marbles of Plymouth and other places in South Devon, but without a trace of fossils.

6. In the hills further to the N.W. are beds of grauwacke, and of calcareous slate with courses of impure limestone, &c., associated with great masses of trap. These beds contain many fossils, especially corals, among which abounded the *Favosites polymorpha*, and other Devonian forms. From these facts we think it obviously follows that the beds of the greater part of this section (extending eight or nine miles in length, without taking into account its undefined southern extremity) are Devonian, and that the whole series is overlaid by the mountain limestone.

In a subsequent traverse by Hof and Naila to Gerolsgrün we found black flinty slate, with carbonaceous laminæ (*kiesel schiefer*); much splintery altered slate associated with trap; alum slate with iron stone (near Naila); grauwacke penetrated with quartz veins, associated with trap, and almost passing into a quartz rock; soft earthy slate with dark-coloured calcareous bands, &c. We mention these phænomena in the order in which they occurred; but the dips were continually changing, and we found no fossils; and out of such materials we do not pretend to put together any consistent section.

Near Gerolsgrün the beds are more free from the influence of trap; and in some fine quarries of sandstone, flagstone, and grauwacke slate, we found fossil shells (*Delthyris*, &c.) and some impressions of small plants. At Langenau, not far from this place, is a bed of marble; and a little to the north of it, is a bed of impure coal, which they have attempted to work. Of this we saw specimens: but we did not visit the spot, as the works were filled with water. As phænomena like those just noticed occur in the Rhenish provinces both above and below the great Westphalian limestone, we do not pretend to determine the exact place of the series of beds in the neighbourhood of Gerolsgrün.

Gerolsgrün to Prusseck.

From Gerolsgrün we made our last traverse to the S.W. as far as Prusseck, visiting the celebrated quarries near Elbersreute by the way. The early part of this traverse was through forests and over rounded hills, that gave no good sections; but we marked on the road side much *kiesel schiefer*, much arenaceous flagstone and red shale (like the "red drab" of Pembroke and Devonshire), and one fine mass of black limestone. Respecting the age of this series of rocks we

offer no opinion, as we found not one fossil among them; simply remarking, by the way, that their mineral characters agree well with those of the Devonian system.

From Elbersreuth we made a short traverse to the N.W. and completed the following section. See Pl. XXIII. fig. 16.

1. Contorted masses of arenaceous flagstone and earthy schist, through which at one point bursts out an amygdaloidal greenstone.

2. Marble breccia, the structure probably produced by the vicinity of the eruptive trap, as is hypothetically represented in our section.

3. Beds of hard grey limestone with many Orthoceratites and large Encrinites, and we believe also with traces of *Clymenia*, &c. Dip. W.S.W.

4. A great precipitous gorge, beyond which the great Clymenia limestone rises at an angle of 40°, dipping about E.S.E. Its fossils are very abundant; and from this spot Count Münster has obtained his finest species of *Clymenia*.

5. Under the whole limestone series are earthy schists containing *Cardiola*.

In addition to the fossils peculiar to the beds above described, are several species in common with the limestones of Wetzlar, Oberscheld, and Dillenburg. In England the Cardiola is indeed an upper Silurian genus, but on the whole evidence we have little doubt that the calcareous rocks here described are Devonian, and nearly on the parallel of the calcareous series in the neighbourhood of Hof.

It would require much labour and many traverses to arrange systematically all the masses of limestone that appear between Hof and Prusseck, and the chain of the Fichtelgebirge. Count Münster has, we believe, determined three distinct bands of limestone containing *Clymeniæ*, but they are not geologically far asunder, and if our views be correct they all belong to one system.

We here terminate our remarks on the calcareous series north of the Fichtelgebirge; acknowledging their imperfection, and especially lamenting our present inability of connecting these deposits with those which are expanded farther north on the banks of the Saal. At the same time we may remark, that our visit, however rapid, satisfied us on one important point (and it was the chief object of our visit to the Fichtelgebirge), viz. the age of the great calcareous masses we have just described. Before our examination they had been classed with the *oldest* Palæozoic rocks: but seeing that these masses are overlaid by true carboniferous limestone, and that they contain the *intermediary* types so often before alluded to, we were convinced on the spot that they ought to be classed with our Devonian system.

We also believe that the rocks, which occupy the mountain tracts of Franconia immediately to the north of the calcareous masses above described, are the equivalents of the slaty grauwacke of the Rhine, and therefore on the parallel of the Silurian system. But we wish not to dwell on opinions which we are unable to confirm, either by the evidence of sections, or by lists of characteristic fossils.

Such is the result of our examination of the older rocks of Franconia. Our general conclusions respecting the succession in the Rhenish provinces in Belgium, and in the Hartz, which are based upon a much more extensive and accurate survey, have been offered in the previous parts of this memoir. Our opinions are now presented to the Society in the best form we are able to give them, as inductions from all the facts we have been able to bring together, supported by such natural analogies as bear upon the questions of classification. We may have been led into some mistakes by a false interpretation of the evidence (often of a kind very intricate and difficult to disentangle); but we deny that we have in any instance turned ourselves away from the evidence that was before us, and based our conclusions on a preconceived hypothesis. The general results appear, as far as they go, to confirm the justness of the methods by which the geologists of this country have toiled to mark out the succession of their formations; and we think also the justness of the conclusions at which we had arrived in former papers, respecting the true sequence of the older formations of Great Britain.

XXV.—*On the Fossils of the Older Deposits in the Rhenish Provinces; preceded by a general Survey of the Fauna of the Palæozoic Rocks, and followed by a Tabular List of the Organic Remains of the Devonian System in Europe.*

By the Viscount D'ARCHIAC and M. EDOUARD DE VERNEUIL,
Members of the Geological Society of France, &c.

[Read December 15, 1841.]

Plates XXV. to XXXVIII.

INTRODUCTION.

On publishing in these Transactions, and in the English language, a work which we at first intended for the Geological Society of France, it may perhaps be useful to make known the motives by which we have been guided. For several years the great questions of Biology raised by the study of fossils had called our attention to those deposits which were first formed on the surface of the globe, and we thought there might be found upon this same surface important materials for the history of life, —materials which had hitherto been too much neglected; we also thought that any general conclusions upon this subject would appear immature before subjecting those beings which were first developed to a more profound examination.

Whilst the same idea had led Mr. Murchison to make the first great step in the zoological classification of the deposits beneath the carboniferous limestone by the establishment of the Silurian and in conjunction with Mr. Sedgwick of the Devonian systems, we were occupied in collecting the fossils which are found in the same beds in France, in Belgium, in the Eifel, and in various parts of Germany. One of us in particular, during several journeys through the Rhenish provinces, had collected numerous materials, having been actively seconded by the modest and learned geologists of these provinces, who, animated by the true love of science (a disposition more usual in Germany than in other countries), are always ready to help those who manifest the desire of forwarding its progress.

We shall particularly mention M. Erbreich, Inspector of Mines at Siegen; M. Schnur, Professor at Trèves; M. Dannenberg, Mining Engineer at Dillenburg; Dr. Hasbach and M. Pongard of Daun; and we are happy here to offer them our grateful thanks for the assistance we have received from them in connexion with this subject. Without their aid it would have been very difficult for us to have recognized the general laws of classification of these ancient rocks amid the disorder which reigns among them. This useful cooperation had then enabled us to amass a tolerably complete collection of facts relating to the fauna of these

deposits, and we had proposed to commence the description of them, when one of us was induced by Mr. Murchison to accompany him to the Rhenish provinces and there examine some of the fossiliferous beds, with the stratigraphical position of which Professor Sedgwick and himself had become familiar.

These gentlemen had already surveyed the Fichtelgebirge, the Hartz, Westphalia, the Eifel, Belgium, &c.; and, enabled by a long and careful examination of the Silurian and Cambrian deposits in England, to unravel the frequently tangled thread of the true succession of these ancient deposits, they had already compared and placed in the relative positions the greater part of the ancient deposits of Germany, and thus held, as it were, the key to the principal divisions which might be established among them. It was then, that they proposed to us to unite our efforts with theirs, and to accompany the new classification of the Palæozoic rocks of the Continent with the description of the fossils of these deposits; a proposition which we could not but accept, and with the greater readiness, since the larger part of our fossils had been collected in the provinces of the right bank of the Rhine, precisely where these gentlemen had found the greatest mass of normal facts suitable to be used as the basis of other approximations. This concurrence of circumstances, already so much in our favour, added still more value to our palæontological researches, inasmuch as the place assigned to our fossils in the series of beds was much more precise, and in relation with geological divisions deduced from other considerations.

Such was the object we at first proposed to attain, but which the more profound study of our subject has extended, even to a degree that we had not foreseen. Prof. Sedgwick and Mr. Murchison, in order to establish their classification in Western Germany, had commenced from a foundation laid by them in the west of England, and it was by analogies which they discovered in the succession of the deposits in the Rhenish provinces, that they assigned to them, as well as to those of the Eifel and Belgium, the true places in the series. This proceeding, so rational on geological considerations, ought, we conceived, to be followed still more closely in the study of the fossils; and we devoted ourselves to a careful examination of every published work relating to this part of the science, at first in the country itself by de Hüpsch, Blumenbach, Schlotheim, Klöden, Goldfuss, Beyrich, Bronn, and Hermann von Meyer; then in the West, upon the Eifel, by Steininger; upon Belgium by Morren, Davreux, Dumont, and de Koninck; upon the various parts of the British Isles by Martin, Fleming, Miller, Sowerby, Phillips, Murchison, Lonsdale, &c. In the East the works of Pusch, Zenke, and Sternberg, also of Count Münster upon the Fichtelgebirge and the environs of Elbersreuth, claimed our particular attention. It was no less necessary to consult those of Wahlenberg, Dalman, Hisinger, and Böek upon the ancient deposits of Scandinavia and its dependent islands; and further still, the writings of de Buch upon Silesia and

some parts of the north of Russia, while those of Eichwald, Pander, and Fischer upon various parts of that vast empire, were also to be carefully considered. Lastly, we could not omit the study of the valuable papers published on the older deposits of North America, either in the United States by MM. Green, Conrad, Troost, De Kay, &c., or in England by Dr. Bigsby and Mr. Stokes. If to this already considerable mass of published documents be now added the observations which one of us had collected in several parts of Europe, it will be seen that we were partly in possession of the elements of a general work on the palæontology of the ancient formations.

Once engaged in this course, we had only to complete our researches by a comparative examination of what had already been done, not only in Europe but also in North America, where the deposits of this age are developed upon a scale of much greater vastness; and lastly, we were to add to all this such positive information as is found in various scientific Transactions, or given by various travellers upon other parts of the globe. After having eliminated the frequent repetitions in the genera, and particularly of species, by comparison of the descriptions and figures given by authors, as well as by that of the numerous specimens which one of us has collected, we have obtained results from this first general sifting which we have thought it might be useful to make known on this occasion, at least in a summary manner. Surrounded by all these hitherto scattered and consequently ill appreciated riches, we have thought it requisite to pause, and take a retrospective glance in order to verify the course taken by science within ten years, and to expose rapidly its progress and its present condition before continuing our march.

We had therefore a twofold reason for placing this summary at the head of our memoir, and making it form the first part. In the second we have described the greater portion of those fossils of the ancient deposits of the right bank of the Rhine which were still undescribed or imperfectly known, and to them we have added some species from the Eifel. We have endeavoured to be simple, clear and precise in our descriptions, but we have omitted nothing which was necessary either to characterize the species or to distinguish them from their cognate species. That which zoologically constitutes a species is not sufficiently defined to allow us to limit our remarks to the enumeration of a few isolated characters; it is necessary to express all of them, because it is from the whole taken together that the species results; and this method is the more necessary for the fossils of the ancient beds, because they are rarely found complete in all parts. If it be observed that many authors have described and figured very incomplete organized remains, of which they neither knew the dimensions nor all the characters, the necessity of being more severe in labours of this sort will be felt, in order to avoid encumbering the science with a multitude of names which really recal to the mind nothing more than objects without form or interest.

We have already stated, that the object of Professor Sedgwick and Mr. Murchison's memoir is to give a detailed account of the proofs in Western Germany and in the neighbouring countries of the equivalents of the Silurian, Devonian, and Carboniferous systems which are so finely developed in England, and particularly the beds representing the Devonian system; for the other two were already well known, although not distinctly limited. The journeys performed by one of us with Mr. Murchison in various parts of Russia subsequent to the first construction of our tables have afforded us the means of so materially improving them, and of enlarging our general views, that with the approbation of that author we have interpolated some of the chief results of the Russian expeditions in the following pages; thus anticipating in some degree what will hereafter be brought before the public in a separate work by Mr. Murchison, M. de Verneuil and Count A. Keyserling. This table, which forms the third part of our memoir, is extracted from the '*Spécies général de la Faune des Terrains Anciens*,' which we are at present occupied in completing. To each species we have added a synonymy, which, although not fully extended, will always suffice to remove all uncertainty about it. We have also carefully avoided citing any localities unsupported by our own observations or by undoubted authorities, and we have been equally careful in referring each species to its proper bed, whether exclusively belonging to the Devonian system, or whether represented at the same time in one of the other two systems, or in all three at once.

PART I.

A General Survey of the Fauna of the Palæozoic Rocks.

When the development of organized beings in each formation or great system of rocks is studied on a sufficiently extended scale, changes more or less distinct may be observed as the inquirer proceeds in certain directions; and these changes are equally evident whether the system be considered in the direction of its vertical dimensions, that is, in the order of the successive beds, or in the direction of its horizontal or geographic extent. In the latter case the modifications presented by the fauna of the system are comparable to what may be observed at the present time, not only as regards animals which live in different latitudes, but also as regards those which are found upon continents or in seas more or less distant, but placed under the same parallel. Already one of us has endeavoured to discover the law, *cæteris paribus*, according to which these various changes were effected in the tertiary and secondary deposits, and the details into which we shall enter upon the animal organization of the ancient beds, tend to confirm that law relating to the distribution and the modifications which species undergo in the same system of deposits*.

* Mém. de la Soc. Géol. de France, t. iii. p. 291; Bull. t. x. p. 168, and t. xii. p. 43.

Mr. J. Phillips thinks that the Testaceous Mollusks preceded the *Polyparia*; but it may be remarked that limestones are rare in the oldest beds, which are almost always formed of slates, grauwacke, or quartzite, then in a state of more or less argillaceous mud and of more or less impure sand, sometimes fine, sometimes coarse, constituting an unfavourable foundation for the stony *Polyparia*; but this does not follow in relation to the naked, the gelatinous, the phytoid or corneous *Polyparia*, or even other more elevated beings, such as the *Medusaria*, which may have existed before. If the waters of this first period contained very little carbonate of lime, and if this cause have also contributed with the preceding to the rarity of the stony *Polyparia*, it must also have had some influence over the *Testacea*. These latter also would only have appeared when circumstances had become more favourable, and they might have been preceded by a great quantity of soft animals, such as the *Actiniæ*; an hypothesis which would moreover be confirmed by the bituminous matter contained in many rocks in which we do not find any organic remains. As to the silex, it does not appear to have been found in these waters in a favourable state for the existence of sponges, which are rare in these ancient deposits comparatively with what are observed in the secondary periods.

The first seas have been said to have been but of small depth, and that the temperature, being more uniform than it is now, there resulted a greater uniformity, both organic and inorganic, in the character of the deposits; and it is added, that it is only in consequence of the upraising of the beds that the asperities of the globe's surface became more distinct, the seas deeper, external circumstances more varied, and animalization also more diversified. If the mineral characters of the ancient rocks were more similar to each other than those of the following periods, it may be attributed to the circumstance, that all the primary sediments resulted from the alteration and decomposition of crystallized rocks differing very slightly in their elementary composition. As to the greater uniformity of the organized beings, it will appear much less decided than it has long been thought, if, as we are about to do, the animals of each great class be considered successively. And lastly, the slight depth of the seas, deduced, according to Conrad's notion, from the absence of Cephalopods with an involute shell, is on the other hand contradicted by the presence of gigantic Cephalopods with a straight and very fragile shell, which could only live in the great ocean and in very deep waters.

The French translation of the Manual of Geology by Mr. De la Beche, which appeared in 1833, contains lists of fossils which at that time were considered rather extensive. These lists comprehend 589 species, distributed in the coal-measures (properly so called), in the carboniferous limestone, and in the grauwacke group. At present, the same series of beds, constituting the Carboniferous, the Devonian, and the Silurian systems, present, after deducting the repetitions, 2698 species of

animals, belonging to 326 genera, distributed into classes and in each system according to the following table. It is necessary, however, to inform the reader, that in the number of species given in the table there are not included, for want of description, or sufficiently accurate figures, 1st, the species determined by M. Hœninghaus and noticed in the French translation of Mr. De la Beche's Manuel; 2nd, those mentioned by M. Eichwald in his memoir on the Silurian System of Esthonia; 3rd, those alluded to by M. Sandeberg de Weilburg, in a letter addressed to M. Bronn, and inserted in the 'Neue Jahrbuch für Mineralogie,' &c. We have also not taken into consideration the distribution of fossil species in the older formations of the south of Ireland, as indicated by Mr. Weaver, because there appears to be some uncertainty about the true geological position of several of these fossiliferous strata. Lastly, the beautiful work of M. de Koninck not having begun to be published till after the completion of our table, we have been able to avail ourselves of only a manuscript list which he had the politeness to give us in April 1841.

RECAPITULATION OF THE FAUNA OF THE PALÆOZOIC ROCKS.

Classes.	Genera.	Total number of Species.	Number of Species in Silurian System.	Number of Species common to Silur. & Dev. Syst.	Number of Species in Devonian System.	Number of Species common to Dev. & Carb. Syst.	Number of Species in Carboniferous System.	Number of Species common to Silur. & Carb. Syst.	Number of Species common to the three Syst.	Number of Species in doubtful Systems.
Pisces*	31	78	8	...	50	...	20	...	...	...
Crustacea	46	216	135	7	32	2	24	2	1	36
Insecta	4	4	...	...	...	...	4	...	...	...
Mollusca, *Ord.* Cephalopoda	20	448	82	10	199	6	168	2	2	22
——— *Ord.* Heteropoda	2	64	15	6	22	3	36	1	2	5
——— *Ord.* Pteropoda	1	11	6	1	4	...	2	...	...	...
——— *Ord.* Gasteropoda	46	382	63	7	116	16	225	5	...	10
Conchifera, *Ord.* Brachiopoda	15	568	230	30	182	28	229	7	3	12
——— *Ord.* Monomyaria	9	161	33	3	60	5	77	1	...	...
——— *Ord.* Dimyaria	38	302	49	9	145	5	126	1	2	2
Annelida	4	11	4	...	5	...	2	...	...	...
Radiata	34	163	42	1	59	10	75	1	3	3
Foraminifera	indet.	...	...	...	indet.	...	indet.	...	...	...
Polyparia	65	260	115	36	107	4	83	1	2	2
Infusoria	indet.	...	...	...	...	...	indet.	...	...	...
Incertæ Sedis	11	30	25	3	3	...	1	1	...	5
Total §	326	2698	807	113	984	79	1072	22†	15	97‡

* The numbers that we have given for the genera and species in this class will be augmented when the discoveries made by Dr. Malcolmson in Scotland, Mr. Asmus in Livonia, Courland, &c., shall have been published.

† The species in this column may probably at some future time be united to those of the next, since it may be supposed that they might have lived during the Devonian period, in the beds of which future researches will not fail to discover them.

‡ The greater number of species in this column are from North America.

§ In the above recapitulation of Palæozoic species we necessarily depend in many instances upon the names and descriptions of foreign authors. Not having had it in our power to compare all the original forms, we conceive that, though by the deduction of several names which we have ascertained to have been applied to the same shell in distant countries, the numerical aggregate may be diminished for the present, yet the amount will doubtless be more than sustained by future discoveries.

We will now take a general survey of these several classes successively, commencing with the more simple and ascending to the more complicated beings. We shall point out the principal genera which they contain, their predominance in any one of the systems or in any country, and we shall follow, so to speak, their distribution over the surface of the globe during these three great periods, which commence with the first traces of life and end with the Magnesian Limestone* of England (the Zechstein of Germany, or Permian system of Russia). See letter of Mr. Murchison, Phil. Mag.

In presenting this abridged Table of our present knowledge, we do not forget that researches will produce some changes in our numbers, and may modify the relations which we have established; but this is the necessary consequence of the progress of science, and we shall only rejoice at it: as the errors of determination must be proportioned to the number of species, the results will not be sensibly altered by them.

General Remarks on the several Classes.

I. *Incertæ Sedes.*—The remains of organic origin, the characters of which, far removed from those of all known types, do not permit us to assign them their proper place in the series, must naturally belong to the most ancient beds, and, in fact, it is in the older slaty schists of Carmarthenshire that the serpuliform bodies, regarded by MacLeay as sea-worms, and to which Mr. Murchison has given the names of *Nereites*, *Myrianites*, and *Nemertites*, are found. The *Polymeres Demetarum* of the same author belongs to the Llandeilo beds. The *Graptolites* or *Prionotus* (of which fifteen species have been pointed out, undoubtedly too many, as Dr. Beck thinks) belong to the Silurian system, both in Europe and in North as well as South America, and the greatest number of them are peculiar to the lower beds of the system. It is probable that the *Annulites* which Mr. MacClelland found in India in the mountain district between Lohooghat and Almorah, in the province of Kemaon, belong also to the most ancient deposits†. As to the *Tentaculites*, they ascend through all the Silurian beds, and penetrate even into the Devonian limestone of the Eifel and their equivalents, both in Europe and in North America. One species has been pointed out in the south of Africa. The *Cophinus* and *Spongiarium* belong to the Ludlow beds; and lastly, the *Receptaculites Neptuni*, Defr.‡ (*Ischadites Königii*, Murch.), which is also found in the Ludlow beds, may likewise be seen in

* Although we completely adopt the views of Mr. Phillips in considering the Magnesian limestone as containing organic forms of the Carboniferous system, and though we extend this view to the Zechstein and to the Permian system, nevertheless the species of these latter beds have not yet been compared with sufficient care by us to be comprehended in the following considerations.

† Journ. Asiatic Soc. Bengal, vol. iii. p. 628, and vol. iv. p. 520.

‡ Dict. Sc. Nat. tome xlv. p. 5.

the Silurian slates and the Devonian limestones of Belgium and the Eifel, as well as the *Pleurodyctium problematicum* of Goldfuss*.

II. *Infusoria.*—Numerous remains which evidently belonged to animals of this class have been recognized by M. Ehrenberg in the silex of the carboniferous formation collected by M. Helmersen upon the banks of the Volga in the vicinity of Twer. This very recent observation, not yet published, confirms our views relative to the development of organized beings on the surface of the globe.

III. *Polyparia.*—We are not aware of the existence of any naked *Polyparia* in the oldest beds. Of Corallines, the *Cellariæ* and the *Sertulariæ* appear very rarely, whether the traces of them have disappeared, or whether these animals were actually few in number. The *Spongiaria*, as well as the reticulated *Polyparia*, are but little spread in them comparatively with the stony Zoophytes. Among these latter we shall mention the *Stromatopora*, of which one species in particular, the *Str. concentrica*, Goldf., is very abundant in the Silurian and Devonian deposits in England, in the Eifel, and in the Rhenish provinces; also on both sides of the Ural, and in the state of Tennessee in North America†. The *Reteporæ* were particularly developed during the Carboniferous period; but the species from which the genus *Fenestella* has been formed, are more numerous in the Dudley and Wenlock beds than in their equivalents of Gottland and Esthonia. Two of these species pass into the Devonian system. The *Gorgoniæ* are not uncommon in the Palæozoic rocks. One of them, the *G. ripisteria*, Goldf., appears to have lived during the three periods. The *Lithodendron* is more particularly seen in the last of them; the *Cystiphyllum* in the two first in England, and in the Devonian system in Belgium and in the Eifel.

The great genus *Cyathophyllum*, such as it is established by Goldfuss, is one of the most important, as well on account of the number of species as for their profusion in all the periods, and the presence of some of them in the most distant countries. Nine species are Silurian, seventeen are Devonian, and eight are Carboniferous; and six are common to the two first systems.

It is particularly in the Devonian rocks upon the banks of the Rhine and in the Eifel that this genus is most extended. It is also very plentiful in the Silurian rocks of Scandinavia, and in North America upon the banks of Lake Huron, likewise in the states of Ohio, New York and Tennessee. It is to be observed that this genus is a dismemberment from the true *Astreæ*, which, with

* M. Goldfuss, Petref. vol. ii. p. 286, has inquired whether this organic body may not be referrible to the Mollusca; being of opinion that it was an animal of that class provided with foliaceous branchiæ, and had the power of affixing itself to shells.

† Memoir on the Organic Remains in the Valley of the Mississippi, Trans. Geol. Soc. Pennsylvania, vol. i. part 2. p. 248.

the *Meandrinæ* and the *Caryophyllææ*, form at the present day the coral reefs and islands of intertropical oceans*. Among the *Strombodes*, a genus consisting but of few species, the *S. vermicularis* of Lonsdale (*Cyathophyllum* of Goldfuss), is common to the two older systems. *Caninia*†, a genus containing few species, is at present peculiar to the Carboniferous system. The *Cateniporæ* (with a single exception, which is even doubtful) characterize the lowest system in Russia, in Scandinavia, on the banks of the Rhine, and in England, as well as in North America: the *Syringoporæ*, on the other hand, are pretty equally disseminated; two species are common to the Silurian and Devonian systems, and one, the *S. reticulata*, Goldf., common to Europe and America, is found in all the systems. In Russia this genus particularly characterizes the Carboniferous period.

The *Favosites*, including the *Calamopora* of M. Goldfuss, are not less important than the *Cyathophylla*, although the number of species be less: sixteen are distributed in the Silurian beds in England, in Germany, upon the banks of the Rhine, in Scandinavia, Esthonia, and Ingria, or the district to the south of St. Petersburg; as well as in North America in almost all those places where the oldest deposits are developed, that is, throughout an extent of nearly 1400 miles from east to west, from the Alleghany chain to Engineer Cantonment upon the Missouri, and of 2400 miles from north to south, or from the shores of the Arctic Ocean and the great lakes to the very centre of Alabama. Of the sixteen species, the six most abundant over these immense surfaces, *i. e.* the *Favosites* or *Calamopora alveolaris*, *Gothlandica*, *polymorpha*, *Spongites*, *basaltica*, and *fibrosa* (of which one, the *F. Gothlandica*, occurs in New Holland), continue to be found in the Devonian system, in which they are not less constant in England, in the north of France, in Belgium, in the Eifel, upon the banks of the Rhine, and in Russia. A single species (*F. infundibulifera*) appears to be peculiar to that system, and seven are peculiar to the Carboniferous period.

The *Auloporæ* are plentiful in the Silurian and Devonian beds, which they do not go beyond; and of five species four are common to these two systems; and lastly, the *Alveolites* and the *Favosites*, genera very much reduced according to the latest works, are represented in the three systems.

When taken collectively, the *Polyparia* are nearly similarly developed in the Silurian and Devonian systems, and thirty-six species are common to them. This, amounting to about a third of the species in each, is much more considerable than for any other class; for the *Brachiopoda*, which, next to the *Polyparia*, contain the greatest number of species common to both beds, have only one-seventh. In the

* The *Caryophyllææ*, the *Astreæ*, and the *Strombodes* are but of slight importance in these ancient beds, when the view in which we regard *Cyathophyllum* is taken.

† Michelin, Supp. Dict. des Sc. Nat. tome ii.

Carboniferous system, in which the calcareous rocks are nevertheless very extensive, rather more than a sixth less are found than in the two preceding, and four only are common to the Devonian system. Lastly, there are three species only found in all the three periods.

IV. *Foraminifera.*—The *Foraminifera* of the Palæozoic formations have as yet been very little studied, and we are well acquainted only with those which have been pointed out by M. Fischer in the carboniferous limestone of the government of Wladimir and the heights of Samara on the Volga, in which escarpments more than two hundred feet thick are entirely composed of them *. Mr. Phillips mentions remains of this class in the Devonian limestone of Cannington Park in North Devon, but without detailing their characters or the number of genera and species. It is moreover very probable that further researches will make us acquainted with a greater number of Palæozoic *Foraminifera*, analogous to those found in the secondary, tertiary and modern formations, wherever circumstances may have been favourable to their preservation.

V. *Radiata.*—The remains of animals of this class almost all belong to the great family of *Crinoidea*. The *Asterias* are very rare, and of *Echinodermata* four *Cidarites* alone are quoted in the Carboniferous system, in Ireland †, Scotland ‡, England §, Belgium ‖ and Russia ¶, and some fragments have been pointed out in the Devonian system. Our attention will not be particularly arrested by many genera of *Crinoidea*, which contain only two or three species, and of which the greater part have not been noticed except in a single locality, whether Silurian, Devonian, or Carboniferous; but we will pass on to the most important genera.

The *Cupressocrinites*, scarcely more than one excepted, are Devonian, from the Eifel and the right bank of the Rhine. The *Pentremites*, of which fourteen species are known, are, on the other hand, almost all Carboniferous. It is nevertheless worthy of remark, that six species are stated by Dr. Troost to be associated with *Calceola*, *Calymene*, *Terebratula Wilsoni*, &c., in Ohio and Tennessee, in beds probably older than the mountain limestone**. In Europe a single species is mentioned at Brushford, in North Devon, in the Devonian beds††; and it ascends into the carboniferous limestone (Ratingen), in which formation the genus attained its fullest development. The *Poteriocrinites* are all from the Carboniferous series, and are

* In their last expedition in Russia, Mr. Murchison and M. de Verneuil ascertained that these *Foraminifera* (*Fusulines* of Fischer, Oryct. Govern. de Moscou; *Alveolines* of d'Orbigny) characterise the upper beds of the mountain limestone, and range over very distant and extensive districts.

† Dr. Buckland's Bridgewater Treatise, vol. i. p. 416.

‡ Ure's Rutherglen, pl. 16.

§ Phillips, Geol. Yorks., part 2, p. 208.

‖ De Koninck, Recherches Anim. Foss. Belgique.

¶ Eichwald, Jarhb. für Miner. 1840, p. 627.

** Trans. Geol. Soc. Pennsylvania, vol. i. part 2, p. 224.

†† Phillips's Palæozoic Fossils, p. 29.

found in Yorkshire, in the neighbourhood of Bristol, and in Tournay. The *Platycrinites*, of which nine are Devonian, fifteen Carboniferous, and three common to both systems, are found particularly in the mountain limestone of England and Belgium, and in the limestones of Devonshire and the Eifel. The twenty-three species of *Actinocrinites* are, on the contrary, equally disseminated in the three systems, and are met with in England, in the Eifel, upon the banks of the Rhine, and in Sweden. Three are Devonian and Carboniferous, and one is quoted from the province of Bolivia *. The *Cyathocrinites* have nearly the same geological distribution: of the twenty-seven species known to us, nine are Silurian, from England, Scandinavia and the adjacent islands; ten are Devonian, from the south-west of England, from the Eifel, and from Elbersreuth; and lastly, fourteen are Carboniferous, from England, Belgium, and the beds of the same age in the centre and south of Russia. Two species, the *C. pinnatus*, Goldf., and *C. rugosus*, Miller, are common to the three systems. The *Melocrinites* of Goldfuss (one only excepted from the mountain limestone of Stolberg) are all Devonian, from the Eifel; and the same may be said of the *Rhodocrinites*, one of which (*R. verus*) is quoted by Goldfuss in the Eifel (Petref.), and by de Buch in the Devonian beds of Russia (Beiträge Russl. p. 62).

On recapitulation we observe that the species of *Crinoidea* increase from the lower toward the upper series in the proportion of 42 : 59 : 75. There is only *one* species common to the two lower systems, while on the other hand ten belong to both the Devonian and Carboniferous systems, a circumstance exactly the reverse of what we have remarked of the *Polyparia*.

VI. *Annelida.*—This class of animals appears to have been but very slightly developed during the older periods, if we may judge by the paucity of their remains; possibly the erratic species and those which live in sand may have existed in great numbers without having left any traces, while only those which secreted calcareous coverings, as the *Serpulæ*, though perhaps not more abundant, have been preserved to the present age. Four species of *Serpulæ* are pointed out in the Silurian system†, six occur in the Devonian, and two in the Carboniferous.

VII *a*. *Conchifera dimyaria.*—The great difficulty of becoming well acquainted with the inside of bivalve shells, such as the hinge, the muscular impressions and the palleal impression, which are so rarely well preserved in the deposits with which we are occupied, should induce caution in admitting the generic approximations and decisions that have hitherto been made; nevertheless we have been led to adopt the denominations which have been assigned to them by authors in consequence of the impossibility of verifying the generic characters and the specific distinctions of a great number of these shells.

* D'Orbigny, Voyage dans l'Amér. Méridionale.

† Silur. Syst. p. 700.

The shells of the *Tubicolæ* appear to be completely wanting in the Palæozoic formations. The *Pholadariæ*, the *Solenaceæ*, the *Myariæ*, the *Mactraceæ*, and the *Corbulaceæ*, are very seldom represented. Among the *Nymphaceæ* the *Sanguinolariæ* are the most plentiful, particularly in the Devonian system, in which there are sixteen species, found in the limestones of the Eifel and of Elbersreuth. Two of these are found in the lower system, and the grauwacke of the Rhenish provinces contains five. Ten are Carboniferous, the greater part from England, and some of these reappear at Peretki in the Valdaï and in the government of Kaluga. The *Sanguinolaria angustata*, Phil., and *S. sulcata*, Münst., are common to the whole series. Of seven *Lucinæ* five are Devonian and from the Eifel, and the remaining genera of this family are unimportant. A single *Cyclas* is mentioned in the freshwater limestone, subordinate to the coal-beds of Westbury in Staffordshire. (Silur. Syst., p. 84.) The *Veneres* are Carboniferous, and the *Pullastræ* Devonian; they are only mentioned as found in England and Belgium.

The family of *Cardiacea* increased greatly during the long accumulation of Palæozoic sediments. The numerous forms of the shells of this family were then extremely varied, as they were during the secondary and tertiary periods, and as they are in the present seas. We shall see as we proceed, that in general those genera which have been capable of resisting all the revolutions of the globe, and which from the commencement showed this tendency to an almost infinite variety of form, but have preserved certain characters which bring them near to the primitive type, have not ceased to exhibit the same polymorphism even to the present time.

Several divisions have recently been established in the genus *Cardium* of the older beds, which we adopt as subgenera. The *Cardiomorphæ** are Carboniferous and from Belgium; the *Lunulacardiæ*† are Devonian, from Elbersreuth and the Fichtelgebirge; the *Cardiolæ*‡, one only excepted, are also Devonian, and from the Clymenia limestone of Elbersreuth; the *Pleurorhynchi*§ or *Conocardia*‖ (a subdivision in which we only leave the new species¶) are of little importance. The genus *Cardium*, as we now keep it, still includes fifty-three species: the Silurian beds contain five which are of slight interest, but one of which passes into the Devonian system; forty-four are from the Clymenia and Orthoceratite limestone of Elbersreuth and the corresponding beds of the banks of the Rhine. The *C. palmatum*, Goldf., is the most common of these species in Westphalia, the Duchy of Nassau, the country of Waldeck, the Fichtelgebirge, and it is also found in Nova Zembla**. In the upper

* De Koninck, Recherches Anim. Foss. Belgique, p. 101, 1842.—(*Note, April* 1842.)

† Count Münster, Beiträge, Heft iii. p. 69, 1840.

‡ Broderip, Silur. Syst., p. 617, 1839.

§ Phillips, Geol. Yorkshire, part 2. p. 210, 1836.

‖ Agassiz.

¶ We have provisionally left in several new genera, such species as were not known before under another name.

** A specimen from that country is in the Museum of Paris.

system there are seven species, of which one, the *C. aliforme*, Sow., is common to the preceding system, and is found in Ireland, England, Belgium, and at Elbersreuth. Lastly, *Isocardiæ* and *Cypricardiæ* also appear occasionally in the several systems. We must further observe, that the greater part of the *Cardiaceæ* of these ancient seas are of much smaller dimensions than in those of the following periods, in which the species attained (like the greater part of the *Acephali*) larger and larger dimensions without presenting on that account less varied forms.

There is nothing very particular about the *Nuculæ* of this epoch: there are twelve species in the inferior system, mostly in the Silurian grauwacke of the banks of the Rhine, several in England, and others are found in Scania in diluvium; seven are from the Devonian limestones of the Eifel and Elbersreuth, and fifteen from the mountain limestone of Ireland, England, and Belgium. The *Cucullææ* are particularly found in the Devonian beds of the south-west of England, and one of them occurs in the Silurian rocks of the Cedar Mountain in the south of Africa*. The *Arcæ*, of which one only has been pointed out in the Silurian system, afford three species to the middle system in the Eifel, at Paffrath and at Elbersreuth, and thirteen to the carboniferous limestone of Derbyshire, Belgium, Silesia, and the north of Russia.

The *Megalodontes* are peculiarly Devonian; and one species, the *M. cucullatus*, Sow., is characteristic of this system in the south-west of England, as well as upon the right bank of the Rhine. The *Modiolæ* and *Mytili*, rare in the Silurian system, are more abundant in the beds which surmount it. These shells are frequent enough in the *Orthoceratite* and *Clymenia* limestones of Elbersreuth, as well as in the mountain limestone of England, Belgium, Ratingen, Silesia, and Russia. Two *Anodontes* are mentioned by M. Eichwald as found in the carboniferous limestone of the coal region of Donetz†; and of twenty-two species of *Unio*, twenty-one belong to the coal-measures of England and Scotland, and of the environs of Liège and Werden.

Thus it will be seen that the *Conchifera dimyaria* are irregularly disseminated in the three systems, in which the species of each system are represented in an ascending series by the numbers 49, 145, and 126; and of these species nine are Silurian and Devonian, and five are Devonian and Carboniferous.

VII *b*. *Conchifera monomyaria*.—The *Acephala monomyaria* present only a small number of genera in the seas which precede the deposit of the upper new red sandstone or Trias. Count Münster enumerates nine species of *Inoceramus* from the limestones of Elbersreuth and the Fichtelgebirge. One of them, the *In. vetustus*, Sow.‡, is found also in the mountain limestone of Yorkshire, Belgium, and

* Mr. Murchison, Silur. Syst. p. 653. † Jahrb. für Min. 1840, p. 732.

‡ This shell, according to the observations of M. de Koninck and our own opinion, should be considered a *Posidonia* (June 1842).

in the Devonian beds of the banks of the Rhine. The *Pterinææ*, widely disseminated during the Silurian epoch, particularly in the grauwacke of the Rhenish province and in the state of New York, become rarer in the beds of the middle period in Devonshire and the Eifel. Two species of this epoch are common to the preceding system, and five are reckoned in the Carboniferous period in Belgium and at Ratingen. The *Aviculæ*, on the contrary, increase from below upwards. Seven are mentioned in the lowest system in England, in the north of France, in the grauwacke of the banks of the Rhine, and in the Eifel, and also in Scandinavia. One of the most frequent, the *A. reticulata*, His., passes into the middle system: twenty-three belong to these last-mentioned beds, from Devonshire, the Eifel, Elbersreuth and the Fichtelgebirge; and twenty-four to the upper system of Yorkshire, Belgium, the banks of the Rhine, and Silesia. The *Posidoniæ*, whose generic characters are still so ill-defined, are found lower down in the series in North America * than in Europe, where they begin to appear only in the Devonian system of Elbersreuth. They are particularly abundant in the culm-measures of Devonshire, and in the carboniferous slates of the banks of the Rhine. The *P. Becheri*, Bronn †, is the most common of these latter.

The increase in number of species from the lower to the upper beds is still more decided in the *Pectines* than in the *Aviculæ*, for only two are known in the Silurian, even if the grauwacke of Glatz in Silesia does really belong to the first system; but fourteen species are found in Devonshire, the Rhenish provinces, and the Volkof; and thirty-two in the Carboniferous system of the north and west of England, in that of Belgium, the banks of the Rhine, Silesia, the Valdaï hills and Vitegra in Russia, and even in the province of Bolivia in the centre of South America ‡.

Thus four genera alone had acquired any importance during this long series of deposits, and we much doubt if the family of the *Ostracea*, as well as the great genera *Lima* and *Spondylus*, which, setting off from the Muschelkalk, have been increasingly developed until the present time, had any real representatives in the ancient seas before the Zechstein epoch. It is in limestones above the true Carboniferous system, but yet containing *Producti* and *Spiriferi*, that one of us has this year discovered an *Ostrea* near Arzamas, in Russia §. As to the numerically specific increase of the *Conchifera monomyaria* in the three systems, it is represented by the numbers 33, 60, and 77; of these, three species are common to the first and second system, and five to the second and third.

VII *c*. *Brachiopoda*.—If the *Mollusca monomyaria* and *dimyaria* are in these ancient

* New York States Geological Report, 1840, p. 454.

† Leonhard's Zeitung für Miner. 1828. ‡ D'Orbigny, Voyage dans l'Amérique méridionale.

§ This and other facts before alluded to in Russia are explained in a memoir by Mr. Murchison, M. de Verneuil and Count Keyserling, now in course of reading before the Geological Society of London.—*March* 1842.

beds represented only by a feeble development in comparison with that which they exhibit in the secondary and tertiary periods and have since acquired in the present seas, the *Brachiopoda*, on the contrary, display a variety of forms, an abundance of species, and a profusion of individuals greater than we find in any other epoch. Notwithstanding the constancy of the fundamental type of the animals of this order, the subtypical forms have, during the deposition of the various Palæozoic rocks, undergone changes and developments often the reverse of each other; we therefore pause a few moments to consider the interesting and striking relation of these forms with the antiquity of the beds in which they occur.

The true *Producti*, which we distinguish from those *Brachiopoda* provisionally retained by us under the name of *Leptæna*, do not appear to have existed during the Silurian period, either in Europe or in other parts of the globe. Of four species noted in the Devonian system, and found in the south-west of England, in the north of France, in the Eifel, at Refrath, and in Russia, three are common to the Carboniferous system. The *Pr. subaculeatus*, Murch.*, is the most constant in the middle system of the north of France, of Belgium, and of the Eifel, and it extends even into the northern and central parts of Russia.

This genus, on the contrary, increased so greatly, both in number of species and in dimensions, during the Carboniferous epoch, that it might alone, so to speak, be taken to characterize it; the *Productus Martini*, *P. antiquatus*, *P. comoides*, *P. lobatus*, *P. giganteus*, and *P. punctatus*, of Sowerby, are profusely disseminated not only through the Carboniferous system in Ireland, Scotland, the north and west of England, in France and Belgium, and on the banks of the Rhine, but also in the basins of northern, middle and southern Russia, upon both flanks of the Ural, and lastly, most of them are found in the carboniferous rocks of North America †. Of seventy-two species of *Productus* of this period, the greater number are found in the mountain limestone of Yorkshire, Derbyshire, the province of Liège, at Ratingen, and in the north of Russia; but we must also remark, that they do not cease to be observed even in the beds of the coal-measures, as we know that they occur in them at Coalbrook Dale ‡, or in those districts in which the mountain limestone no longer forms a distinct platform at the base of the Carboniferous system, but where it is confounded with other coal-measures, as at Sablé (France), in the north and south of Russia, and in North America. In the province of Bolivia, M. Alcide d'Orbigny has pointed out nine species of *Productus*, and he has shown

* Bull. Géol. Soc. de France, tome xi. p. 255, 1840.

† The *Productus antiquatus* is found at Spitzbergen with other carboniferous forms, also in South America, on the shores of Lake Titicaca (*April* 1842).

‡ See Mr. Prestwich's Memoir on the Structure of Coalbrook Dale, Geol. Trans., 2nd Series, vol. v. Part 3.

that the *Calcaire à Producte* is blended with the coal-measures. The genus is still to be seen above the coal-measures, but disappears after the magnesian limestone or the zechstein, and the corresponding beds in the governments of Archangel, Vologda, Perm and Orenbourg *.

The *Leptænæ*, among which we comprehend the greater part of the *Strophomenæ*, present, according to our views, characters which place them naturally between the *Producti* and the *Orthides*; but as relates to their distribution among the three systems, it is analogous to that of the species of this latter genus, for there are twenty-two Silurian, ten Devonian, and four Carboniferous. The Silurian species, among which we may particularly distinguish the *L. sericea* (Sow. Sil. Syst.) as one that is found in the most distant countries, are principally from the border counties of England and Wales, and from the grauwacke of the banks of the Rhine. Some are found in Scandinavia and in the dependent isles, also in the state of New York †. The *Leptæna sarcinulata* (*L. lata* of M. de Buch), the most common species in Europe, and which passes into the Carboniferous system, has been mentioned, but with a doubt, as occurring in the south of Africa ‡. Of ten Devonian species, one, the *L. analoga*, Phill., is also found in the superior system; it is one of the most common not only in England but in Belgium, and in the states of Ohio and New York.

The genus *Orthis* §, which is much more numerous than the genus *Leptæna*, follows, in its vertical distribution, a precisely analogous ratio of decrease. Sixty-four species are Silurian, thirty-five Devonian, and fifteen Carboniferous. Nine species, common to the first two systems, serve to denote an intimate connexion between them, such as the *Polyparia* have already demonstrated. The *O. Callactis* is the most exclusively Silurian species, and is found in England, in Scandinavia, in Russia, in the state of New York, and in the south of Africa. The *O. lunata* (Sow. in Sil. Syst.), and *O. testudinaria*, Dalm. ‖, which also pass upwards into the Devonian system, are frequent in various parts of Europe and North America.

* We are happy to inform the palæontologist that M. de Buch has just completed a monograph of the genus *Productus*, which will complete his works upon the *Brachiopoda* family, on which he has thrown so much light. (*June* 1842.)

† We have seen in the interesting collection of Mr. Logan, who is well acquainted with the geology of some parts of North America, that the *Leptæna sericea* is one of the most common shells at Montreal and in the limestone of Upper Canada. (*May* 1842.)

‡ Silur. Syst., p. 583, *note*.

§ We have united several of M. Pander's genera to *Orthis*, and have much reduced the number of species which he had established provisionally.

‖ *Orthis lunata*, *O. testudinaria*, *O. hybrida*, *O. basalis* and *O. elegantula*, characterized by their bent striæ, the first of which turn back to the hinge, are difficult to distinguish from each other by the insufficient descriptions which are usually given.

The species peculiar to the middle system have very seldom been found identical in many distant regions, and the same may be observed in regard to those of the superior or Carboniferous system. The *O. Umbraculum*, as it is defined by M. de Buch, seems to bind together the Devonian and Carboniferous systems in several parts of Europe, and the *O. rugosa* (*Leptæna*, Dalm.) the two inferior systems on this side of the Atlantic, as well as on the other, where it is found in the Catskill Mountains, in the beds of Trenton Falls, and in Pennsylvania.

The species for which we have provisionally retained the generic names of *Delthyris* and *Cyrtia* are all Silurian, and from Scandinavia and the state of New York.

The *Spiriferi* * present, so to speak, an intermediate distribution between that of the *Producti*, the number of which increases very rapidly in the superior system, and the *Terebratulæ*, the species of which are almost equally disseminated in the three systems. In the same manner, the *Spiriferi* increase from below upwards, but follow a much less rapid progression than that of the *Producti*, being represented by the numbers 29, 50 and 74. There are but few species exclusively Silurian, which are found throughout a certain extent of country, and consequently may be regarded as really characteristic of the inferior system. In the middle system we find the *S. heteroclites* (de Buch) in Devonshire and on the right bank of the Rhine; the *S. speciosus* (Schlot.) in Devonshire, Belgium, the Eifel, Russia, the Ural, and in the Cedar Mountains north of the Cape of Good Hope; the *Sp. Verneuilli* (Murchison †) in the Bas Boulonnois, Belgium, Voroneje in Central Russia, and as far as Smeinogorsk and Berosowa in the Altaï. The species exclusively Carboniferous are very numerous in the mountain limestone of England and Belgium, and a few of them extend to the several basins of Russia, where they occur with other peculiar species, and M. d'Orbigny has found some of them in beds of the same age in South America. The *Spiriferi* of the Carboniferous system are in general distinguished by their less numerous, wider and more rounded, and frequently dichotomous plaits. The species also attain greater dimensions, are more commonly globular or rounded in form, and are generally smoother than in the older formations. Among the *Spiriferi* common to two systems, we may mention, as being both Silurian and Devonian, the *Sp. trapezoidalis* (*Cyrtia*, Dalm.), which is found in England, in Belgium, upon the banks of the Rhine, in Scandinavia, and in the north of Russia; and the *Sp. macropterus* (Goldf.), from the Eifel, the Rhenish provinces, Russia, Kunawur in the Himalaya ‡, the Cedar Mountains in the south of Africa, the state of Ohio, and the lower Silurian beds of the state of New York. The latter is the

* We have united *Trigonotreta* to *Spirifer*.

† Bulletin Géol. Soc. de France, tome xi.

‡ Dr. Royle's Illustrations of the Botany, &c., of the Himalaya Mountains, Part XI. Fossils, pl. 3. f. 23, and p. xxix.

only species that has been hitherto met with in the four quarters of the globe. Among the ten Devonian and Carboniferous species, we may notice the *Sp. oblata* (Sow.), as being found in Ireland, England, Belgium, the Eifel, and as occurring in Van Diemen's Land; likewise the *Sp. glaber*, Sow., over all Western Europe and in the state of Ohio. The three species which are met with throughout the entire series of ancient deposits are, the *Sp. octoplicatus*, Sow., the *Sp. crispus*, Dalm., and the *Sp. striatulus*, Schlot., but the *S. striatulus* is extremely rare.

The *Pentameri* are hitherto exclusively Silurian. This genus is largely represented in the Ural chain, and species different from those of Europe are distributed from Bogoslofsk in the north to Bielozeskoi in the south. (*April* 1842.)

The *Strygocephali*, on the contrary, are peculiar to the Devonian system, and the *S. Burtini* (Bronn) is very characteristic of its beds on the right bank of the Rhine and in Devonshire. These shells appear to be very rare in the strata of the same age so highly developed in Russia, for we have found only a single individual in the Ural.

We have retained provisionally the name of *Atrypa* for those shells which have not yet been placed in any other genera, but it must be acknowledged that this group is not zoologically well characterized, and that its distribution in the three systems is but of minor interest: twenty-six Silurian species occur in England and Scandinavia; twenty-one Devonian are found in the south-west of England, as well as eight which belong to the Carboniferous system.

The *Terebratulæ*, as we have already mentioned, are almost equally distributed through the three systems in Europe; there are fifty Silurian, forty-nine Devonian, and forty-four Carboniferous. This near equality of distribution is maintained in relation to such of them as are common to two systems, for there are thirteen which are both Silurian and Devonian, and ten Devonian and Carboniferous. The greater part of the *Terebratulæ* peculiar to the Silurian system are from the border counties of England and Wales, as well as from Scandinavia, and some are found in Esthonia, Ingria, south of St. Petersburg, and in the province of Bolivia. Conrad does not admit the existence of a single true *Terebratula* in the Silurian system in the United States; but we must remark, that this zoologist cites shells under the name of *Atrypa*, which, in our opinion, are true *Terebratulæ*, and which have in general been regarded as such down to the present time.

In the middle system the *Terebratulæ* abound, particularly in Devonshire and in the Eifel, on the right bank of the Rhine, and in the limestones of Elbersreuth. Among the species peculiar to this system, the *T. ferita*, and the *T. concentrica* of de Buch, are very characteristic in Devonshire, the Bas Boulonnais, the Cotentin, Belgium, the Eifel, the environs of Cologne and Russia: one of the most interesting in Russia is the *T. Meyendorfii*, nob., which is very abundant on the

banks of the river Volkof and in the government of Pskof; it is also found near the source of the Vitchedga, not far from the northern Ural. Those which belong both to the Silurian and Devonian systems are found over a much more considerable space; thus the *T. Wilsoni*, Sow., of England, is to be met with also in Belgium, in Russia, in the island of Gottland, and in the states of Ohio and Tennessee. The *T. prisca* and *T. aspera*, Schlot., are found in England, in the north of France, in Belgium, in the Eifel, upon the banks of the Rhine, in Scandinavia and the islands of the Baltic, also in Livonia, Esthonia, Ingria, the Uralian chain, on the banks of the Thracian Bosphorus, near Smeinogorsk on the north side of the Altaï; in America in the states of Tennessee, Ohio and Pennsylvania; and, finally, in the slaty clays of Moscow (New York) and on the banks of Lake Erie.

The superior or Carboniferous system in Ireland, Yorkshire, Derbyshire and the west of England, encloses a vast number of *Terebratulæ*, as well as the mountain limestone of Hainault and of the provinces of Liège and Namur. They are not so numerous in the carboniferous beds of the north and south of Russia. The species peculiar to this system are not in general extensively distributed; those which are common to it and to the middle system have, on the contrary, been collected very far apart; thus the *Terebratula hastata* (Sow.), from Ireland, England, and Belgium, has been found in Russia and as far as the Altaï chain; the *T. acuminata*, Sow., is common to both systems in England and in Belgium; and lastly, the *T. Pleurodon*, Phill., occurs not only throughout Western Europe, but also in Silesia, Livonia, and the Valdaï near Smeinogorsk in Asia. It is not certain that any species traverses the entire series of Palæozoic rocks.

If it were sought to establish any general difference of character in the *Terebratulæ* of the three systems, it might perhaps appear that the striated or very finely plicated species with sharp folds prevail in the Silurian; that in the Devonian these characters have a tendency to become less strongly marked, and that the species with cross striæ and with a rugose surface, in consequence of the decussation of these striæ by longitudinal folds, become more abundant; and, lastly, that the Carboniferous species have their folds larger and less numerous, and that the shells are more frequently smooth and even, and that, like the *Producti* and *Spiriferi*, they attain dimensions much more considerable.

The genus *Ungulites* of Pander (*Obolus*, Eichw.) is known to be plentiful in some Lower Silurian grits in the neighbourhood of St. Petersburg, but it does not extend to the west of Revel. Two *Craniæ* are mentioned in the Eifel, and one species is not rare in the Silurian beds of the neighbourhood of St. Petersburg and along the shores of the Baltic in Esthonia. The *Lingulæ* and *Orbiculæ*, often but indistinctly characterized, have been found in the several systems, but no species appears to pass from one to another. Lastly, the *Calceola sandalina*, Lam., which fairly pecu-

liarises the Devonian period in the west of England, Belgium, the Eifel and the right bank of the Rhine, has also been noticed in the states of Tennessee* and Ohio.

If we reflect for a moment upon the four principal divisions of the great family of the *Terebratulæ*, that is, the *Producti*, the *Orthides*, the *Spiriferi* and the *Terebratulæ* proper, all the others being capable of combining with these, we shall perceive that their proportions and their mode of distribution in the three systems being known, one might, by deduction from such knowledge, judge *à priori* what would be their relative development in succeeding periods. Thus the *Producti*, which are so suddenly and copiously displayed in the Carboniferous system, would not, it might be inferred, at once disappear in the next overlying deposits, nor survive long after the exceptional circumstances which had caused so rapid an extension; and, in fact, they disappear above the zechstein and the contemporaneous beds both in Western and Eastern Europe. The *Orthides*, although decreasing upwards, had still sufficient representatives in the superior system to survive the epoch of the coal-measures; and one species, *O. Laspii*, Buch, lived during the epoch of the zechstein, being found in that formation at Ropsen, near Gera. The *Spiriferi*, on the contrary, increasing slowly upwards, ought to have survived both the *Producti* and the *Orthides*, and they are found even to the upper parts of the lias. Lastly, the *Terebratulæ*, which maintained a nearly equal proportion during the whole of the great series of Palæozoic rocks, uninfluenced by the changes which took place in the ancient seas, ought to have long outlived all the other genera; and we observe, in fact, that they have so resisted all the revolutions of which our globe has been the theatre, that they abounded in profusion at all periods, and that they are numerous in the present seas: but by a singular anomaly we do not know any species of *Terebratula* which lived during the three Palæozoic epochs.

It has been seen by the details which we have given of the species common to two systems, that those which have been found most extensively in a vertical direction, or which have the greatest range in the successive deposits, are generally those which have the most extended geographical distribution, and have been met with at the greatest number of places and at very considerable distances; and indeed it may easily be conceived that the species whose organization enabled them to live through several consecutive periods, would at the same time be those which could exist under the most different external conditions.

A last remarkable result of the inverse distribution of the species of each genus of *Brachiopoda* in the three systems, as shown in the foregoing Table, is, that the total of the species in each of them is but slightly different, and that the number

* Dr. Troost, Organic Remains, Valley of the Mississippi, Trans. Geol. Soc. Pennsylvania, vol. i. p. 249.

of the species common to two of these systems is almost perfectly equal, whether in reference to the first and second or to the second and third.

VIII *a. Gasteropoda.*—Like the *Conchifera monomyaria* and *dimyaria*, the Gasteropod Mollusca were far from presenting during the Palæozoic such numerous genera and species as during the following periods, and their feeble relative proportion is even yet more striking. The *Phyllidianæ* and the *Calyptracianæ* have some representatives in the three systems, but they do not possess any particular interest. Shells related to the genus *Melania* are very plentiful in the mountain limestone of Belgium; and it is the same with the *Naticæ*, which are also very common in Yorkshire and in the Rhenish provinces, and one species, the *N. subcostata*, nobis, is very abundant in the Devonian beds of Paffrath. Some species are found in the Carboniferous system of the north of Russia, and two in the province of Bolivia. Shells related to *Neritæ* have been pointed out in the Silurian beds of England, in the Devonian system in England and at Elbersreuth, also in the mountain limestone of Belgium and the British Islands. The *Schizostomæ*, which begin the series of genera characterized by a fissure in the right lip, and at that time so well developed, are peculiarly Devonian, but are still few in number. The *S. radiata*, nob., is found in Devonshire and the Eifel.

We pass over some unimportant genera to come to the *Euomphali*, which were very numerous during the three ancient periods. Seventeen are Silurian, and are very plentiful in that system in England and Scandinavia. The *E. rugosus*, Sow., *E. funatus*, id., and *E. alatus*, His., are particularly characteristic of it. Among the seventeen of the middle system found in England, on the banks of the Rhine and at Elbersreuth, the *E. annulatus*, Phil., alone is found both in Devonshire and in the Rhenish provinces. The species common to the two lower systems have a wider geographical range; the *E. gualteriatus* of Schlotheim, in particular, is stated to occur at Christiania, in the islands of Gottland, Aland, and Dago, at Revel, Paffrath and Chimay. The Carboniferous system is still richer in species than the preceding; they are frequent in the mountain limestone of Yorkshire, Belgium, the banks of the Rhine, and north and central Russia. The *E. pentangulatus* and *E. Catillus*, Sow., are characteristic of this system throughout that extent, and the latter, according to American authorities, is also found upon the shores of Lake Erie and in the state of New York. The *E. Labadyei*, nob., and *E. Serpula*, de Kon., are found both in the Devonian and Carboniferous systems.

Among the *Cirri* (a genus that we retain provisionally) there are also some Devonian and Carboniferous species. The *C. rotundatus*, Sow. (*Euomph. Dionysii*, auct.), is frequent in the beds of the upper system, and a conoidal variety is found at Paffrath.

The *Pleurotomariæ*, still more numerous than the *Euomphali*, are very unequally

distributed in the three epochs: the number of species increases from below upwards in the following progression, viz. three are Silurian, nineteen are Devonian, and forty-nine Carboniferous. The species in the first system are unimportant. Those peculiar to the second are particularly developed in Devonshire and in the corresponding deposits of Paffrath and Villmar on the right bank of the Rhine, although there are really very few species common to the two localities. The *P. expansa*, Phil., *P. monilifera*, id., *P. Defrancii*, nob., and *P. limbata*, Phil., lived through the two latter periods. The *P. Delphinuloides*, Goldf., and its numerous varieties, seem also to belong to both systems. The *Pleurotomariæ*, which, with many other genera, are lost sight of from the coal-beds to the lias, reappear in great number in the lower beds of the oolitic series and decrease successively in the newer deposits, until they are represented in our present seas only by the little genus *Scissurella*.

The *Trochi*, much less abundant than the *Pleurotomariæ*, are nevertheless distributed in the same manner in the three systems, whether in a horizontal or vertical direction. The *T. helicites*, Sow. (in Murch. Sil. Syst.), is both Silurian and Devonian. The *T. Bouei*, Stein.*, belongs to the second system in the south-west of England, in the Eifel, and at Paffrath. The *T. Yvanii*†, Lev., appears to have lived in the last two periods. The species of *Turbo* are more equally distributed in the three systems. The *Turritellæ* of the ancient epochs are in general insufficiently characterized, in consequence of their having almost always lost the mouth. Among the twenty-six species which now remain, of which it will undoubtedly be necessary to suppress some, three are Silurian, eight Devonian, and fourteen Carboniferous.

The *Murchisoniæ* ‡, on the contrary, are neatly characterized shells, and appear to have been peculiar to the ancient beds: four species are Silurian, ten Devonian, and four Carboniferous; and three are both Devonian and Carboniferous; namely, the *M. spinosa*, Phil., *M. angulata*, id., and *M. tæniata*, nob. These shells are particularly abundant in the Devonian beds of the banks of the Rhine. The genus *Loxonema*§, which consists of shells formerly classed among the *Terebræ* and *Melaniæ*, is also more exclusively Devonian. The *L. rugifera* and *L. tumida*, Phil., are nevertheless found in the two upper systems. The *Buccina*, only one species of which is noticed in the Silurian system, are less rare in the intermediate, and twelve are reckoned in the superior system. The *B. acutum* and *B. imbricatum* lived in large numbers during the Devonian and Carboniferous periods in England, in Belgium, and on the banks of the Rhine. The *B. arculatum*, Schlot.,

* Mém. Géol. Soc. de France, tome i. † Ibid. tome ii. p. 39, 1835.

‡ See *posteà*, p. 356, and Bulletin Soc. Géol. de France, tome xii. p. 154, 1841.

§ Phillips, Pal. Foss. Cornwall, &c. p. 98, 1841.

presents numerous varieties in the limestones of Paffrath, as well as the *B. Schlotheimii*, nob., which is also found in the corresponding beds of Devonshire. Those shells of the older beds which have been united to *Buccinum*, differ nevertheless in the characters of the aperture sufficiently to authorize the establishment of the subgenus proposed by Phillips under the name of *Macrocheilus**. With respect to the other genera of Gasteropods which have been noticed as represented in the first sedimentary beds, we think it right to say that they are only approximations too incomplete to be mentioned here.

In considering collectively the number of species of this class distributed in each system, a very decided increase from below upwards may be observed, for there are 63 Silurian, 116 Devonian, and 225 Carboniferous ; a progression which appears to have been continuous to the present time, notwithstanding some local and momentary interruptions in the secondary periods.

VIII *b*. *Pteropoda*.—We refer provisionally to this class the genus *Conularia*, of which we know eleven species ; or six Silurian, four Devonian, and two Carboniferous. The *C. quadrisulcata*, Sow., belongs to the uppermost system only, having been wrongly noticed as belonging to the more ancient beds. The *Conulariæ* are spread over the various parts of Europe and North America, and are also found in the south of Africa : they do not appear to show themselves above the coal-measures.

VIII *c*. *Heteropoda*.—*Bellerophon* is a genus peculiar to the Palæozoic deposits of the several epochs, in which specimens are more or less extensively distributed. As in the preceding genera, the species peculiar to any one system are usually found only in a few localities, and consequently it must very rarely happen that any one species should characterize a system through any great extent of country. Fifteen are Silurian, twenty-one Devonian, and six are common to the two series. Among these we shall mention the *B. Murchisoni*, d'Orb., of the tilestone or lowest stratum of the old red sandstone of England †, and which is also found in the slates of Wissenbach ; then the *B. trilobatus*, Sow. (in Murch. Sil. Syst.), *B. carinatus*, id., and *B. acutus*, id. The last, which belongs to the lower Silurian beds of England, reappears in the limestones of Elbersreuth, and is found in the ancient beds of Southern Africa. The Carboniferous system is still richer than the preceding ; it contains thirty-six species, which are very common in the mountain limestone of Scotland, Ireland, England, Belgium, and of the north and centre of Russia. The *B. Verneuilli*, d'Orb., of Visé has been likewise found in the Altaï. Lastly, the *B. Urii*, Fleming, (*B. Atlan-*

* Palæozoic Fossils of Cornwall, &c., p. 103 *et seq.*, 1841.

† We are informed by Mr. Murchison that he has no objection to admit his tilestone group of the Old Red or Devonian system into the Silurian system. Indeed in his work he shows by the fossils that these tilestones are beds of passage between the two systems, and that they were grouped with the Old Red chiefly on account of their geographical position, structure and colour.—*March* 1842.

toides, d'Orb.), and *B. apertus*, Sow., common to the three systems in England, Belgium, and on the banks of the Rhine, show their close mutual relations. In North America this genus equally characterizes the Palæozoic rocks, not only in all the northern states on the shores of the great lakes, but also of those which occupy the centre of the great vale of the Mississippi, and on the west of that river even to the foot of the Rocky Mountains in the Missouri, the Prairies and the Arkansas.

VIII *d*. *Cephalopoda*.—If we judge of the number of animals of this class which peopled the primary seas only by the remains of their solid parts which have been preserved until our time, we should readily regard them as nearly equal to the *Brachiopoda*; it is, however, probable that those seas furnished nourishment to great numbers of naked Cephalopods which have left no evident trace of their existence.

The *Nautili* are rare in the Silurian system: we have seen descriptions of only four in Europe, of which one is stated to be found in the island of Gottland *, two occur in Esthonia †, and one in the Caradoc sandstone of Llandovery ‡. Only two are Devonian, from the south-west of England; but forty are Carboniferous, and are distributed through the beds of this system in Ireland, England, Belgium, on the banks of the Rhine, and they extend as far as Donetz and even to the Ural chain. The *N. globatus*, Sow., *multicarinatus*, id., *cariniferus*, id., *tuberculatus*, id., and *sulcatus*, id., are those which are found at the most distant points. The species of this genus found in the ancient beds are generally small, and some of them have one or two keels, a character which is no longer found in the secondary and more recent periods, in which, moreover, the *Nautili* attain much greater dimensions.

We will here regard the *Orthoceratites* as a great family, in which we shall arrange as genera and subgenera those species which are more or less spiral at their summit, more or less inflated toward the aperture, or those in which may be remarked a siphon, whose singular and varied form indicates important modifications in the organ which occupied it; and we retain the name of *Orthoceratite* for those which are straight and regularly conical.

The *Orthoceratites*, properly so called, are extremely abundant in the deposits anterior to the Carboniferous; and the nearly equal distribution of the species in the three systems is a remarkable circumstance, which we have yet had occasion to notice only in reference to the *Terebratulæ*. The forty-six Silurian species almost all belong to England and Scandinavia; a very few are found in the Upper Silurian rocks of Esthonia §, Ingria, in the beds of Trenton Falls ‖, and in those of Tennessee ¶.

* Hisinger, Lethæa Suecica, tab. 7. fig. 1; Sowerby in MS.

† Eichwald, Syst. Silur. Esthonie, p. 113. ‡ Murchison's Silur. Syst., pl. xxii. fig. 7, p. 642.

§ Eichwald sur le Système Silurien de l'Esthonie, 8vo, 1840, p. 99.

‖ State Reports, New York, 1838, p. 115; 1840, p. 371.

¶ Troost's Memoir Org. Rem. Valley of the Mississippi, Trans. Geol. Soc. Pennsyl., vol. i. pt. 2. p. 248.

Of the forty-seven species of the Devonian system the greater part belong to the limestones of Elbersreuth and the Fichtelgebirge, and they are less plentiful in the beds of the same age on the banks of the Rhine, in the Eifel, Belgium, and the west of England. The seven species which are common to the first two systems are also obtained in the most distantly separated countries: such are *O. Ibex*, Sow. (Sil. Syst.), found in England, at Wissenbach and Gottland; the *O. Ludense*, id., of England, Elbersreuth and Revel; the *O. regularis*, Blum., and *O. Calamiteus*, Count Münster. The fifty-two Carboniferous species have been particularly observed in Scotland, and in the mountain limestone of Ireland, Yorkshire and Belgium. They are not common in the coeval deposits of the north of Russia. The *O. Unguis*, Phil., *O. Steinhaueri*, Sow., and *O. Gesneri*, Mart., have been pointed out as occurring at the most distant localities in Europe. Three species, the *O. cylindraceus*, *O. lateralis*, and *O. giganteus*, are Devonian as well as Carboniferous; and the *O. imbricatus*, Wahl., with *O. cinctus*, Sow., unite the three systems together.

If the great development of the *Orthoceratites* in the ancient seas of our hemisphere be considered, it will appear astonishing that only five or six species should be known in North America, where the contemporaneous deposits are so much more greatly extended; but a sort of compensation is established between the two sides of the Atlantic by means of other genera, as we shall presently show.

The *Cyrthoceratites* are very scarce in the Silurian system, but they are extensively developed in the Devonian, in which are reckoned twenty-one species, from the south-west of England, the Eifel, and the banks of the Rhine. One of these is noticed at the cascade of Montmorency in Canada. Of nine Carboniferous species, eight are from the environs of Tournay, and the ninth, common to this and the preceding system, is found in Devonshire and the north of Russia. Of the *Phragmoceratites*, four belong to the Ludlow beds and two to the limestones of the Eifel and Elbersreuth. Of ten species of *Lituites*, nine are Silurian, and occur in England, Scandinavia, and Esthonia.

We have just remarked upon the rarity of the true *Orthoceratites* in North America, and the same may be observed relatively to these last genera: still this great family is not the less fully represented; only, instead of specific characters, taken from the external shells, much more decided differences may be observed—differences in accordance with the organization of the animals which occupied the shell. If the species which have been made in Europe are more numerous, the types of the genera or subgenera in America are more varied. Thus the *Conotubulariæ* of the state of Tennessee* have only two analogues in Europe, the *O. cras-*

* Troost, Org. Rem. Valley of the Mississippi, Trans. Geol. Soc. Pennsyl., vol. i. part 2. p. 248, 1835.

siventris, His., and *O. cochlearis*, Schlot.* The *Actinoceratites* and the *Conoceratites*, from the island of Thessalon in Lake Huron and from Lake Winipeg, are nearly all peculiar to those countries, as we know of only one European species, which is found in Ireland†. The *Ormoceratites*‡, the siphon of which, when cut through, is characterized by singular volutions, belong moreover to the same regions, as well as the *Orthostoma communis* § of the state of New York, and the *Spirulæ* from Tennessee‖.

Of all the genera which we have as yet recalled to notice, no one has presented so confined a distribution united to so great a local development as the *Clymenia*. Thus, of forty-three species, three belong to the Silurian formation of Esthonia, according to Professor Eichwald; and of thirty-nine Devonian, thirty-five are confined to the limestones of the Fichtelgebirge, Elbersreuth, and Silesia; and of these thirty-five, three are found in Devonshire associated with four others. It is not impossible that some *Goniatites*, whose chambers are not known, and which are found in Silesia and upon the banks of the Rhine, may be true *Clymeniæ*; as the beds which contain them also belong to the Devonian system. A single *Clymenia* has been discovered in the Carboniferous system in Ireland. This genus is absent in the overlying beds intermediate between the Carboniferous system and the muschelkalk; but one species has been mentioned in that deposit. None are at present known in the oolitic beds; and some casts referred to this genus from the chalk of Faxoe, seem to belong to *Nautili*; but the tertiary beds contain some species.

At length the *Goniatites* close our review of the Mollusca, in presenting to us a greater number of species than any one of the genera we have yet mentioned. Nevertheless they begin to appear only with the latest of the Silurian beds, and in but one single locality, the slates of Wissenbach. Starting from this period, they become extremely multiplied in the Devonian limestones of Gattendorf and Schübelhammer, and in some other localities of the Fichtelgebirge and Elbersreuth, concurrently with *Clymeniæ* and a multitude of *Cardiacea*, *Inocerami*, and *Posidoniæ*; while the *Orthoceratites*, the *Trilobites*, and the Trachelipod Mollusca are only to be seen in the beds above them. *Goniatites* are plentiful enough in the deposits of the same age in Westphalia and in the duchy of Nassau, and in those of the south-west of England.

The fifty-nine *Goniatites* of the Carboniferous system are found over a much

* *Orthoceras giganteum* of Sowerby, and an undescribed species from the neighbourhood of Valognes, belong also to this division.

† Bronn. See Mr. Stokes's Mem. Geol. Trans., 2nd Series, vol. i. Pl. XXV. and vol. v. Part 3, p. 707, Pl. LIX. fig. 1, 1840.

‡ Mr. Stokes's Mem. Geol. Trans., 2nd Series, vol. v. Part 3, p. 709, Pl. XL. fig. 1.

§ State Reports, New York, 1838, pp. 115, 119; 1839, p. 63; 1840, p. 370.

‖ Troost, loc. cit. supra.

more considerable extent than the eighty-five Devonian. The mountain limestone of Yorkshire contains the greatest number. Some have been discovered in the upper group of the Carboniferous system in the Ural mountains*. The species most widely distributed are the *G. Henslowi*, Sow., obtained in the Isle of Man, from the culm-measures of Devonshire, in Staffordshire, and at Ecton in the state of New York†; the *G. Listeri*, Mart., from Derbyshire and the province of Liège, stated also to occur in India on the banks of the Ganges‡; the *G. carbonarius* of Goldfuss from Yorkshire and the banks of the Rhine; the *G. sphæricus*, Mart., from Derbyshire, the Isle of Man, Yorkshire, the province of Liège, Herborn, and the state of New York; and lastly, the *G. striatus*, Sow., is met with in nearly all these localities.

The *Goniatites* have been but seldom noticed in the ancient beds of North America; and those which have been mentioned are from the Carboniferous system. According to Conrad there are none in the Trenton group which form the lower part of the Silurian system, and they are extremely rare in the upper beds of the series. The genera *Trocholites* and *Phragmolites* of the state of New York seem to approach in structure the *Goniatites*§.

From the sagacious observations of M. von Buch, naturalists are well acquainted with the characters in which the *Goniatites* or *Ammonites* of the ancient beds differ from the true *Ammonites* of the secondary beds; but if the *Goniatites* themselves be attentively examined, characters will be observed in the exterior contour of their chambers indicative of the antiquity of the system in which they are found. Thus the *G. Nœggerathii*, de Buch, and *G. subnautilinus*, id., from the Silurian schists of Wissenbach, belong to the first section, which is characterized by rounded or very slightly inflected lobes. Of all the families of the *Ammonites*, these have the edges of the chambers the most simple. In the Devonian system the lobes are more decided, angular and linguiform, but the dorsal lobe is constantly simple. In the Carboniferous system, on the contrary, nearly all the species (four or five only excepted) have the dorsal lobe divided. From these to the *Serratites* of the muschelkalk, and thence to the true *Ammonites* of the lias and the later formations, the passage is perfectly gradual in relation to the chambers; but this progression does not appear to exist relatively to the dimensions of the shells, the *Goniatites* being almost always small.

In general the Cephalopods appear to have been much more extensively distributed in the ancient European than in the American seas. As to the number of species in the three systems, it will appear to be much more considerable in the Devonian system than in the two others.

* See the forthcoming work on Russia alluded to *antè*, p. 306.

† State Reports, New York, 1838, p. 110; 1839, p. 62.

‡ De Buch.

§ State Reports, New York, 1838, p. 118–119; 1839, p. 63; 1840, p. 371.

IX. *Insecta.*—It has long been doubted if animals of this class could have lived in the ancient periods; and then, on the other hand, the extreme delicacy of their parts, at least in the greater number of the orders, is such, that a hope could scarcely be entertained that any traces of those which did exist should have been transmitted to us: all doubt on this subject has however ceased, two species belonging to the family of *Curculionidæ* having been found in the coal-fields of Coalbrook Dale, as well as a Neuropterous insect, which closely resembles the genus *Corydalis* now living in Carolina; also a *Libellula*, or an insect related to the *Phasmidæ* *. As to the *Orthoptera* and *Arachnides*, mentioned in the general treatises on the science, we have not yet sufficiently precise indications relative to them to reckon upon here. Count Sternberg has likewise announced the discovery of a fossil scorpion in the coal-measures at Chomle, near Radnitz in Bohemia†. It is further easily conceivable, that, as insects could only leave traces of their existence in exceptional and very rare instances, it is very improbable that we should ever have a satisfactory knowledge of this part of the fauna of the ancient formations.

X. *Crustacea.*—The *Crustacea* of these far-distant epochs belong almost exclusively to the family of *Trilobites*, in which a great number of genera have been established. What we have already said relative to the uncertainty of many of the approximations and determinations of genera and species of bivalve shells, is much more strongly applicable to the *Trilobites*, of which, as it is rare to have at once under our observation any great number of complete specimens of each species, we are reduced to the necessity of taking some isolated and external characters to establish not only a species, but even a genus; and we are only acquainted with the organization of these animals by more or less distant analogies, so that these incomplete characters being the result of the imperfect state of the casts, the uncertainty which reigns throughout this branch of the science, notwithstanding the special works of which it has been the subject both in Europe and in America, may be conceived.

The *Trilobites* begin to appear in the most ancient beds in which any organic remains of the animal kingdom have yet been observed. They seem also to have been peculiar to the Palæozoic epoch, not even continuing so high as the upper part of the Carboniferous system; a circumstance which agrees with their rapid decrease in proportion as they rise from the most ancient Silurian beds towards the succeeding deposits, as pointed out by Mr. Murchison‡.

The *Calymene*, which are very abundant in the Silurian system of Europe, are

* Dr. Buckland's Bridgewater Treatise, vol. i. p. 409; vol. ii. p. 75.

† See Verhandl. Gesel. Vaterl. Mus. in Böhmen, 1835; also Dr. Buckland's Bridgewater Treatise, vol. i. p. 406, and note, vol. ii. p. 74, Pl. 46′. 1836.

‡ Silur. Syst., p. 647, 1839.

not less so in that of America. Of eighteen species, principally from England and Sweden, some are also found in Esthonia, Livonia, and France. The *C. Blumenbachii* of Brongniart is, of all the Silurian fossils, that which has been observed in the greatest number of countries: first at Dudley and in the west of England; then in the slates of Wissenbach and in the grauwacke of Daun; throughout Scandinavia and the dependent islands; in Esthonia *, Ingria, and the west of France; in the Cedar Mountains of South Africa †; in the states of Ohio, New York and Tennessee; and wherever the deposits of this epoch are to be seen from the great lakes as far as Alabama ‡. Of ten Devonian species, the greater part are from the limestones of the Eifel, and from those of corresponding age in the environs of Elbersreuth and in the Fichtelgebirge. Two species are common to the preceding period: one, the *C. macrophthalma*, Brong., to which several names have been given, and which, with the *C. Sclerops*, Dalm., now forms the genus *Phacops* §, has been noticed in nearly all the countries in which we have observed the *C. Blumenbachii*, also at Prague, in the Eifel, and in the state of Virginia; the other, the *C. Tristani* (Brong.), from the west of France, is also found in the grauwacke of the Eifel and to the west of the Cape of Good Hope. The *C. concinna* of Dalman is at present the only species which has been observed in the three systems.

The *Homalonoti*, which are but few in number, are principally Silurian. *H. Knightii* of König ‖ is the most common; it is found in England, in the grauwacke of the Eifel, and upon the banks of the Rhine, also in the Devonian system of the west of England and at Néhou. The *H. Herschelii*, Murch., found in the south of Africa ¶, occurs likewise on the banks of the Rhine.

The *Asaphi* are even more plentiful than the *Calymene*; forty-six species are Silurian, and particularly noticed in England, Scandinavia, Esthonia, Ingria, and North America. *Asaphus caudatus*, Brong., *A. Hausmannii*, id., *A. cornigerus*, id., are the most frequent in the Silurian deposits on both sides of the Atlantic. Six only are from the Devonian system, and eleven are Carboniferous. The *A. granuliferus* of Phillips is found in the two later systems.

Of eleven species of *Paradoxides*, nine belong to the lower system in the west of

* Eichwald, Syst. Silur. Esthonie, p. 70.

† Silur. Syst., p. 654.

‡ It is a curious fact, said Mr. Conrad (Annual Report, 1839, p. 58, 1840), that whilst the *C. Blumenbachii* ceased to exist in New York after the final deposition of the Trenton series, it escaped into remote seas and lived in the æra of the Dudley limestone. The *Cryptolithus tessellatus*, on the contrary, seems to have existed and to have become extinct at the same periods in the seas which deposited the rocks of Llandeilo and Trenton Falls.

§ Emmerich, De Trilobitis; Berlin, 1839. See Von Buch's Beiträge zur Bestimmung der Gebirgsformationen in Russland; Berlin, 1840, p. 48.

‖ Icon. Foss. Sect., Centuria Prima, Tab. VII. f. 85; also Silur. Syst. p. 651, Pl. VII. f. 1–4.

¶ Silur. Syst., p. 652, Pl. VII. *bis*, f. 2.

England, Scandinavia, and the state of New York; two are noticed in Bohemia and one at Elbersreuth, in the middle system. *Illænus* occurs nearly under the same condition: of this genus, one species, the *I. crassicauda*, Dalm., is met with in Scandinavia, Ingria, Brittany, and the west of England; two species are Devonian. At present only five species of *Ogygia* are known, of which three are from the environs of Angers, one from Llandeilo, and one from the banks of the Mohawk in the state of New York. The genus *Brontes* is principally Devonian; the *B. flabellifer*, Goldf., so diffused through the beds of the middle system of the west of England, the Cotentin, Belgium, the Eifel, the banks of the Rhine, and found even on the Asiatic exposure of the Ural, existed also when the upper Ludlow beds were deposited. The *Oleni* are occasionally met with in the first two systems. The *Cryptonimi* are from Ingria and Esthonia *. The genera *Battus*, *Nilæus*, *Lychas* and *Ampyx* belong principally to the Silurian beds of Scandinavia; as the genera *Otarion*, *Ellipsocephalus* and *Conocephalus* probably do to the less ancient beds of Bohemia †. Lastly, the genera *Isoletus*, *Eurypterus*, *Cryphæus*, *Dipleurus*, *Ceraurus*, *Triarthrus*, *Nuttania*, *Brongniartia*, and many others which contain only one or two species, have yet been noticed only in North America. The *Isoletes gigas* appears to be one of the most abundant *Trilobites* in that quarter of the globe ‡.

In recapitulation, there are in the inferior strata 132 species of the family of *Trilobites*, without including thirty-six North American species, of which the greater part are probably found in beds belonging to the Silurian system; there are also thirty-two in the Devonian and twenty-four in the upper system: seven only are common to the two first, while one alone pervades the three palæozoic series.

Among the other genera of the class *Crustacea*, we may mention a *Limulus* from the coal-measures of Coalbrook Dale §; *Cytherinæ*, from the Silurian strata in the island of Gottland ‖ and the neighbourhood of Christiania, also from the Devonian system; and other minute genera, such as *Cypris* or *Cytherina*, *Cypridina*, *Cyprella* and *Cypridella*, belonging to the Carboniferous system of Belgium, Scotland, and some other countries ¶.

Pisces.—If the *Crustacea*, highly elevated as they are in the scale of beings, appear to have been among the first animals on the surface of the globe, such was not the case with the class which succeeds them in organization. The

* Eichwald, sur le Syst. Silur. de l'Esthonie, p. 77.

† Verhandlungen Gesells. Vaterl. Mus. in Böhmen, Ap. 1833, s. 49 *et seq.*

‡ Second Report of the State of Ohio, 1838, p. 247, pl. 8. and 9.

§ Dr. Buckland's Bridgewater Treatise, vol. ii. p. 77, Pl. 46″. fig. 3.

‖ Hisinger, Lethæa Suecica, tab. 1. fig. 1, 2; for Scotland, see Dr. Hibbert's Memoir on the Fossils of Burdie House, Trans. Roy. Soc. Edinb., vol. xiii. p. 169 *et seq.*, 1836.

¶ See de Koninck, sur les Crustacés Fossiles de Belgique. Mém. Acad. Roy. de Bruxelles, t. xiv.

most ancient traces of fishes known to us are not found below the lowermost Ludlow beds, in which remains of the *Pterygotus problematicus* have been found; in the upper beds the species are more common and their characters better defined. The genera *Onchus*, *Sclerodus*, *Plectrodus*, *Thelodus* and *Sphagodus* mark this zone; but it was in the Devonian period that the animals of this class really took possession of the seas. In Scotland, in the west of England, in Courland, Livonia and Lithuania, the Devonian beds contain numerous remains of those remarkable loricated fishes, such as the *Holoptychius* and the *Coccosteus*, or of such as are furnished with aliform appendages or extraordinary fins, as the *Pterichthys* and other allied Ichthyolites. The genera *Cephalaspis*, *Osteolepis*, *Cheirolepis*, &c., are not rare in the old red sandstone of England and Scotland. The most extensively distributed fish of this period was the *Holoptychius nobilissimus*, which is found not only in all those countries we have mentioned, but also in the centre of Russia in Europe and even in Pennsylvania, associated with a *Megalichthys* in beds of the same age. A species of *Coccosteus* is also noticed in North America.

Fishes have also lived in great numbers during the coal period: thus the coal-measures of Sarrebruck have produced the genera *Acanthæssus* and *Amblypterus*; those of Shrewsbury, Coalbrook Dale and Titterston Hill have furnished the *Ctenodus*, *Megalichthys*, *Gyracanthus*, *Ctenacanthus*, &c. The *Holoptychii* seem to pass up from the middle system into this; and *Palæoniscus*, of which the species are abundant enough in the coal-measures of the United States, lived also in the epoch of the zechstein (magnesian limestone or Permian system), a circumstance which further tends to unite zoologically this last-mentioned deposit with the true Palæozoic rocks. Not a single species of fish has hitherto been noticed in any two systems.

Notwithstanding the importance of the class, we can give only this general view of it; the slight special acquaintance we have with the animals which compose it not permitting us to give a more complete idea of the actual state of science in relation to them.

Recapitulation.—The Fauna of the Palæozoic rocks with which we are now acquainted, thus presents 326 genera, containing 2698 species, of which 807 are Silurian, 984 Devonian, and 1072 Carboniferous: 113, or rather more than $\frac{1}{15}$th, are common to the first and second systems; 79, or $\frac{1}{26}$th, are common to the second and third systems; and 15 only, or $\frac{1}{173}$rd, range through the entire series of ancient formations. This latter proportion, being $\frac{1}{72}$nd, if we regard the species pointed out in the Silurian and Carboniferous systems, will also be found in the Devonian. There are 177 species more in the middle system than in the lower, and 88 more in the upper than in the middle system.

The details we have just given of the animalization of the ancient seas during a

space of time probably much more considerable than that during which the secondary deposits were accumulated, show that there was not any sudden and complete change in the organization of the animals which peopled those seas; and that the three Palæozoic systems are combined together zoologically by a small number of species common to all. Nevertheless, the modifications were such, that not only the greater part of the species, but also of the genera, successively ceased to live, in order that they might be, successively also, replaced by others which have disappeared in their turn; while some are persistent through all the periods and still live in our present seas, as if to allow us to compare more exactly the most extreme productions of creation.

If then some few species were capable of resisting all the changes which modified external circumstances during the three ancient periods, it may be supposed that the same was the case during the formation of the less mighty secondary beds; and it will be difficult to admit that the uprisings, which, during the deposition of these latter, changed the face of nature in certain countries, could have occasioned at the same time the complete destruction of animals which then lived in the seas most distant from the theatre of those great phænomena.

The examination and the nature of the review which we have taken of the Palæozoic Fauna appear to us to modify a little the scientific opinion long entertained, that the organic beings of the ancient seas had a simplicity of structure and a uniformity in their distribution, which entirely distinguished them from those characters which the more modern deposits present. This assertion derived its greatest strength from the fact, that the more easily studied secondary and tertiary beds have presented much higher numerical results than the others, and have done it much sooner. If the numerous circumstances which will for a long time, and perhaps for ever, prevent the creation of the ancient periods from being as well known as that of the most recent, be taken into account, it will be seen that species were already very varied and very numerous in the Silurian, Devonian, and Carboniferous seas, and that the general uniformity of their distribution is less than has been stated. We have noticed many genera which lived at only certain epochs and in very limited areas, thus constituting local faunas, comparable to what is observed in the more recent deposits; but this would not prevent other genera or other species which lived in the same localities from existing at the same time at the most distant parts of the earth, and in the most various latitudes.

If certain divisions, such as the *Gasteropoda*, the *Monomyaria*, the *Dimyaria*, and the *Annelides*, had comparatively few representatives in the ancient seas, others, such as the *Polyparia* and the *Cephalopoda*, are not less plentiful than in any of the following periods; and some, such as the *Brachiopoda* and the *Crinoidea*, are infinitely more varied. Lastly, if the development of Palæozoic organism be

considered relatively to the thickness of the beds or duration of the epoch, we shall see, 1st, *that the total number of species always increases from below upwards*; 2nd, *that the progression is very different in each order and in each family, and that this progression is even frequently inverse, either in the different orders of the same class or in the various genera of the same order.* If, on the other hand, this development of the Palæozoic creation be considered relatively to its horizontal extent, or geographically in relation *to space*, it will be seen, 1st, *that the species which are found in a great number of localities and in very distant countries, are almost always those which have lived during the formation of several successive systems*; 2nd, *that the species which belong to a single system are rarely observed at great distances, and that they then constitute local faunæ, peculiar to certain countries; whence it results, that the species really characteristic of a system of beds are so much the less numerous as the system is studied upon a vaster scale* *.

* Our memoir was finished and partly in type when we read with true interest that our conclusions accord with those given by Mr. Phillips in his last work on the Palæozoic Fossils of Devon and Cornwall, pp. 154, 162 and 163.

PART II.

DESCRIPTION OF THE FOSSILS*.

TRILOBITES.

1. *Calymene macrophthalma*, Brong., Hist. Nat. Crust. Foss. Pl. I. f. 5. Pander, Beiträge z. Geog. des Russ. Reiches, Pl. IV. B. f. 8. Murch., Sil. Syst., Pl. XIV. f. 2.

We have found this species in the roofing-slates of Wissenbach. It is known to be one of the most abundant in the Eifel, but, on the contrary, it is very rare in the properly so-called Silurian system. Mr. Murchison remarks, that in England it is much less abundant than the *Calymene Blumenbachii* and the *Asaphus caudatus*. Pander found only a single specimen in Russia. It also occurs at Prague and in North America, but it has not yet been mentioned as Swedish †.

2. *Calymene concinna* ? Dalman, Ueber die Päalden oder die sogenannten Trilobiten, Pl. I. f. 5.

The slates of Herborn are often filled with impressions of the post-abdomen of a *Trilobite* which appears to be related to *Calymene concinna*; but the difference in the age of the beds in which our fossil occurs and the incompleteness of the specimens do not permit us to insist upon their identity with Dalman's species.

3. *Calymene granulata*. Munst. Beitr. Petref., iii. Heft, Pl. V. f. 3, id. Phil. Pal. Fos., Pl. LVI. f. 248. Sedg. and Murch., Geol. Trans., vol. v. Pl. LIV. f. 24.

We found in the limestone of Oberscheld the post-abdomen of a *Calymene*, which appeared to us very like that which Prof. Sedgwick and Mr. Murchison have figured in their Memoir on Devonshire.

4. *Asaphus subtyrannus*, nob.

Tail short and broad; articulations of the lateral lobes much inclined toward the end of the tail, and joined to the middle lobe at a very decided angle. These articulations are united by a membrane which goes all round the post-abdomen, and they are about half as wide again as those of the middle lobe. Both are granulated, but the grooves which separate them are quite smooth.

Width of the middle lobe, 18 millim.; of the lateral lobes, 24 millim.‡.

This *Trilobite* should be placed near to *A. tyrannus* var. *ornata* (Murch., Sil. Syst., Pl. XXIV.), from which it is distinguished by its less slender form and by the disposition of its granulations, which in *A. tyrannus* are seen both on the ridges and on the grooves which separate them. But since, according to Mr. Murchison, individuals of *A. tyrannus* are found which do not present any traces of granulations, it is possible that the examination of a greater number of specimens from Wissenbach might compel us to unite our species to that of Mr. Murchison, which has only yet been found in the lower beds of the

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* We refer to the general Table at the end of this memoir for all the species already described, upon which we have no observations to offer.

† We preserve for *Calymene macrophthalma* the name at first assigned to it by M. Brongniart, and which is the most generally known; but this fossil has received several other denominations which appear to authorise the establishment of the genus *Phacops*, in which M. Questedt has united *C. macrophthalma* and *C. sclerops*.

‡ A millimetre is equal to 0·03937 of an English inch, and a centimetre equals 0·393708 of an English inch. The English inch equals 2·539954 centimetres: thus to bring any number of millimetres into English inches and fractions of inches, it is only necessary to multiply that number by the decimal 0·03937.

Silurian system. Eichwald unites to *A. tyrannus* a fragment of a *Trilobite* discovered upon the coasts of the Gulf of Finland. (Syst. Silur. Esthonie, p. 87.)

Found in the slates of Wissenbach; very rare.

5. *Brontes flabellifer*, Goldf. Nova Acta Acad. Cæs. Leop. Nat. Cur. Bonn, vol. xix. pars 1. Pl. XXX. f. 3.

The post-abdomen of this species was formerly known under the name of *Olenus flabellifer*. The head and body, being extremely rare, had never been figured before the specimen which Goldfuss collected in the Eifel, was given in the Bonn Transactions.

We have observed this *Trilobite* at several places in the *Strigocephalus limestone*, which extend from Elbersfeld to Hagen, and particularly near Mettmann and Lethmate. The genus *Brontes* is one of the most constant in the Devonian system; for besides being found on both banks of the Rhine, Count Munster has collected four species in the *Orthoceratites limestone* of Elbersreuth. One of these, the *B. radiatus*, appears very near, if not identical with, *B. flabellifer* (Müns. Beiträge zur Petrefact., 3 Heft, Taf. V. f. 13). This *Brontes* is also found in the limestones of Devonshire which are of the same age, and M. de Gerville obtained a fine specimen from the limestone of Valognes, the geological position of which is not yet well determined. Lastly, M. de Koninck mentions it in the limestones and lower slates of Chimay and Couvin, beds which also belong to the Devonian system†. We do not yet know if it has occurred in the beds of the same epoch in the Bas-Boulonnois.

Harpes macrocephalus, Goldf., *loc. cit.*, *supra*, Plate XXXIII. fig. 2.

The genus *Harpes* was established by Goldfuss for *Trilobites* found in the limestones of the Eifel. We have found the *H. macrocephalus* in the *Goniatites limestone* of Oberscheld (Nassau). The *H. speciosus* of Count Münster, which comes from the neighbourhood of Elbersreuth, appears to us difficult to distinguish from the species of Goldfuss. Phillips has also found this species in the Devonshire limestones. (Pal. Foss. Pl. LV. fig. 24.)

Homalonotus Knightii, König. Icon. Foss. Sect. Centuria Prima, Pl. VII. f. 85. Murch., Sil. Syst., Pl. VII. f. 1, 2.

This species of the upper Ludlow rock is found also in the slates of Wissenbach and Altenahr.

Homalonotus Herschelii, Murch., Sil. Syst., Pl. VII. *bis*, f. 2.

We have found this *Trilobite* in the greywacke of Daun.

GONIATITES. I. Lobes simple, rounded and slightly inflected.

1. *Goniatites subnautilinus*, Schlot. De Buch, Ann. des Sciences Nat., tom. xxix. Pl. I. f. 9–11.

The sphæroidal form of this almost completely enveloped species distinguishes it from the following, to which de Buch would nevertheless be disposed to unite it, in consequence of the analogy of the lobes.

Wissenbach; rare.

2. *Goniatites Nœggerathii*, de Buch, *loc. cit.*, Pl. I. f. 6, 7, 8. *Discites*, Id. *Ammonites Nœggerathii*. Goldf., see Beyrich, Beiträge zur Petref., 1839, p. 24. Tab. nost. XXV. f. 1, 1 *a*, 1 *b*.

Shell subdiscoidal, subumbilicated; volutions rounded on the sides and on the back. Inner edge straight, and a little excavated above the suture. Six or seven apparent volutions, the last enveloping two-thirds of the preceding. Shell unknown. Siphon indistinct. Dorsal lobe lanceolate,

† Goldius Flabellifer de Koninck, Crust. Foss. Belgique, Mém. Acad. Roy. de Bruxelles, tome xiv. —*Note*, April 1842.

sharp, as deep as it is wide, or double its width if the latter be measured at half its height. Dorsal saddle rounded; lateral lobe very large, slightly curved backward, without reaching the depth of the dorsal lobe, then rising again abruptly toward the inner edge, there forming a lateral saddle more elevated than the slightly evident dorsal saddle, and which joins the suture.

This shell differs sufficiently from that represented by de Buch; but the disposition of its lobes, as well as the identity of its geological position, have decided us to preserve to it the name it has long borne. Its ridges are regularly rounded, and bring it near to *G. subnautilinus*, to which Beyrich has united it. In the figure given by de Buch, the ridges, obliquely flattened toward the back, render the aperture somewhat lanceolate, like that of *G. evexus*, a species which Beyrich also unites with the preceding.

Very common in the slates of Wissenbach.

3. *Goniatites lateseptatus*, Beyrich, Beiträge zur Petref., Pl. I. f. 1–4.

This species is very abundant in the roofing-slates of Wissenbach and in the overlying ferruginous limestone of Oberscheld.

4. *Goniatites Dannenbergii*, Beyr., *loc. cit.*, Pl. I. f. 5.

This species, found in the slates of Wissenbach, appears to be very rare there.

5. *Goniatites compressus*, Beyr., *loc. cit.*, Pl. I. f. 6. *Spirula compressa*, Goldf., v. Dechen, Handbuch der Geognosie, von H. T. De la Beche, p. 536. *Gyroceratites gracilis*, H. v. Meyer. Nova Act. Acad. Nat. Cur. Bonn, tome xv. Part II. p. 59. Id. Bronn. Leth. geog., Pl. I. f. 6.

Dorsal lobe small and narrow, lateral lobe scarcely indicated by a slight inflection of the septum. Volutions exposed and often separated, which Beyrich attributes to the disappearance of the shell. From three to four volutions, each presenting fifteen septa.

Slates of Wissenbach; very common.

6. *Goniatites retrorsus*, de Buch, Ann. Sc. Nat., tome xxix. Pl. II. f. 13. Beyr., *loc. cit.*, Pl. I. f. 10. Tab. nost., Pl. XXV. f. 2, 2 *a*, 2 *b*, and 3, and for varieties *a* and *b*, f. 4 and 5.

Shell nautiloid, inflated, umbilicated; volutions enveloping, and only showing in the umbilicus the height of the inner edge and the suture. From the edge of the umbilicus to the back the surface of the volutions is inclined, forming a regular curve, which is more distinct in the younger volutions. Back limited by two lateral channels which are also deeper in young individuals. Fine and regular striæ set off from the suture, rise almost perpendicularly to the edge of the umbilicus, then turn backwards and form an arch which occupies two-thirds of the side and passes into the channel, there describing an inverse curve whose concavity is turned backward: these striæ then rise abruptly to the back, which they cover, tracing a deep sinus whose concavity is directed forward.

According to Beyrich, the dorsal lobe is small, cyathiform, and as deep as it is wide. Lateral lobe rounded, and twice as deep as the dorsal lobe; its width is equal to its depth. Lateral saddle wide, rounded, reaching the height of the dorsal saddle, and turning a little toward the suture after having passed across half the side.

Var. *a*, fig. 4. This shell is distinguished from the preceding by its less inflated form, and by its dorsal channels being less distinct. It forms the passage to the following.

Var. *b*, fig. 5. This variety is figured and described by Beyrich. It is still more depressed than var. *a*; but its striæ are similar to those of the shell which we regard as the type of the species, and to those of the first variety.

We have thought it necessary to describe and figure the *G. retrorsus* again, because the figure given by de Buch does not agree with his description, and differs also from Beyrich's figure. These two au-

thors describe the *G. retrorsus* as altogether enveloped, while the drawing of the former exhibits a decided umbilicus, and Beyrich's figure does not show well the form of that part of the shell. The three varieties which we have distinguished are all more or less umbilicated.

Oberscheld, Martenberg near Stadtberg, Adorf; common.

7. *Goniatites simplex*, de Buch, Ann. des Sc. Nat., t. 29, Pl. II. f. 8.

In the ferruginous limestones of Oberscheld is found a shell which nearly resembles that figured by de Buch under this name, and which comes from Rammelsberg near Goslar (Hartz).

8. *Goniatites paucistriatus*, nob. Tab. nost. XXV. f. 8, 8 *a*, 8 *b*.

Shell flattish, umbilicated. Volutions regularly rounded, almost completely enveloping and only showing in the umbilicus the inner edge of each volution. Back wide, limited by two decurrent, linear, shallow channels. Volutions ornamented with from fifteen to eighteen simple, elevated, very fine striæ, which, setting off from the suture, go sometimes straight over two-thirds of the side and sometimes turn a little forward, then backward and then forward again into the channel, where they form a narrow and deep sinus. They are then recurved again to pass over the back where they form a second sinus wider, more rounded and not so deep as the preceding. Lobes of the septa unknown.

We have placed this species near to *G. retrorsus*, because it bears some resemblance to it in general form, but it is easily distinguished by the disposition of the striæ and by their small number. At first sight these striæ might be mistaken for the lobes of the septa, but it is easy to ascertain that they only exist upon specimens in which the shell itself remains. We had already observed upon several species from the mountain limestone of Visé (Belgium) zigzag striæ which we might have confounded with the septa, if we had not observed that they do not present any dorsal lobe, and that beneath the shell are found the true lobes of the septa, which are much more simple than the external striæ, and have no resemblance to the pattern formed by these latter.

Adorf, Oberscheld; common.

II. Lobes angular or tongue-shaped.

A. Volutions completely enveloped.

9. *Goniatites cancellatus*, nob. Tab. nost., XXV. f. 6, 6 *a*, 6 *b*.

Shell globular, with rounded, inflated volutions, the last completely enveloping all the others; umbilicus none, its corresponding place being occupied by a slight depression of the inner edge. Back simple, rounded, coalescing with the sides by a continuous curve. From the central depression radiate numerous striæ, which are very fine, at unequal distances, and often bifurcated. They are first directed forward near to the middle of the side, and then turn backward to form a broad and shallow sinus whose concavity is turned forward. At about two thirds of the side, where the inflection of these striæ commences, other striæ, more delicate, but still regular and transverse, cross them obliquely forming a slight undulation, thus producing an elegant chequer-work over the entire dorsal region of the shell.

The form of this species, of which we have not observed the septa, approaches to that of *G. linearis* of Munster, which has only a single angular funnel-shaped lateral lobe.

From the iron mines of Brilon; very rare.

B. Volutions exposed; three lateral lobes.

10. *Goniatites Hœninghausii*, de Buch, *loc. cit. supra*, Pl. II. f. 3. Bronn. Leth. geog., Pl. I. f. 1. Tab. nost. XXV. f. 7, 7 *a*, 7 *b*.

Shell discoid, subumbilicated, volutions depressed, their inner edge inclined toward the suture at an angle of 45°; the lateral portion then describes a slight but regular curve, continuing to the back which is sharp-edged. Four visible volutions are enveloped to about three-fourths of their width. Numerous, unequal striæ set off from the suture and taking a direction obliquely forward, begin to turn back toward the middle of the sides. [The bad condition of the specimen prevents us from determining what their form is up to the back.] Dorsal lobe rather larger than deep; dorsal saddle rounded. First lateral lobe very narrow, lanceolate, sharp, twice as deep as the dorsal lobe. First lateral saddle rounded, rising to double the height of the dorsal saddle, and occupying rather less than a third of the side of the shell. Second lateral lobe as deep and almost as narrow as the first. Second lateral saddle rounded, rising to the height of the dorsal saddle and terminating at a third, shallow lateral lobe which limits the inner edge and ends at the suture.

This species, remarkable for its size, as well as for its form and the number of its septa, of which we have counted forty in a single volution, was first described by De Buch and afterwards by Bronn; but the descriptions, and the figures especially, of these authors, were so incomplete, that we have endeavoured as much as in our power to complete the knowledge of this fine fossil.

Refrath; very rare. Eifel; some fragments.

11. *Goniatites Buchii,* nob. Tab. nost., XXVI. f. 1, 1 *a*, 1 *b*. Var. *a*, f. 2, 2 *a*.

Shell discoid, umbilicated, volutions flattened upon their sides. Back rounded; dorsal lobe narrow, lanceolate and shallow. Dorsal saddle rounded. First lateral lobe lanceolate, sharp and double the size of the dorsal lobe. Lateral saddle rounded, rising much higher than the dorsal saddle and occupying half the side of the shell. Second lateral lobe lanceolate, descending nearly as low as the first. Although in our specimen this part does not show distinctly the termination of the septum, it is probable that there is a third lateral saddle upon the inner edge and perhaps a third lobe, after which the septum continues backward to unite with the suture. In the figure the third saddle only is shown.

Var. *a*, f. 2, 2 *a*. This variety is known by very distinct arched folds upon the middle of the back which become less distinct toward the edges. A portion of the shell being preserved shows that it was ornamented with fine and very close-set striæ, setting off from the suture, turning backward and then rising again abruptly forward toward the edge of the back. They then curve backward again and form a deep sinus which occupies its entire breadth. The arched folds are independent of these striæ and appear only to exist under the striated shell and perhaps only on that anterior part of the shell which is destitute of chambers. The variety appears also to remain smaller than the type of the species.

At first sight the *G. Buchii* might be regarded as intermediate between the *G. intermedius* and *G. carinatus* of Beyrich, but in the first place, it differs from the former in its more depressed general form and in its more flattened sides; from *G. carinatus* in its simple and rounded back, and from both in its simple and narrow dorsal lobe, a character which, added to its form, to the disposition of its lobes and saddles, as well as to the number of its chambers, brings it near to *G. Hœninghausii.*

Oberscheld; very common.

C. Four lateral lobes.

12. *Goniatites costatus,* nob. Tab. nost., XXXI. f. 1, 1 *a*.

Shell flattened. Volutions numerous, rounded, half exposed, ornamented with simple, elevated ridges, twenty-four upon each volution; these ridges set off from the inner edge, occupy two-thirds of the side, then turn forward and become weaker toward the dorsal channel where they are no longer seen. Back wide, rounded, edged by two shallow channels, which become attenuated and disappear from the last volution of large individuals. Dorsal lobe apparently deeply divided. The artist has

given to the drawing of this part of the chamber more precision than the state of the specimen justifies. There are four tongue-shaped lobes, which diminish in depth as they approach the suture. Saddles rounded. Septa twelve to each volution, leaving between each the space occupied by a rib.

This *Goniatites* is one of those which by the general form remind us most of the true *Ammonites*, particularly of those of the family of the *Arietes*.

Collected by M. Dannenberg at Eibach near Oberscheld; rare.

13. *Goniatites costulatus*, nob. Tab. nost., XXVI. f. 3, 3 *a*, 3 *b*.

Shell flattened. Volutions four or five, half-exposed, depressed toward their middle part. Inner edge nearly straight and slightly excavated beneath. Back wide, flattened, bordered by two narrow and shallow channels. Twenty-eight to thirty simple ribs set off from the suture, take a backward direction across half the side, where they are more prominent, then rise again toward the dorsal channel, becoming attenuated so as to disappear completely upon the outer edge of each channel. Besides these ribs, in those parts where the shell has been well preserved, there are fine undulated striæ, which after going forward to the dorsal channels, turn backward to form a sinus which occupies the whole width of the back as in the *G. paucistriatus*.

This species appears to be related to the *G. costatus*, although we are not acquainted with its lobes; but it is distinguished by the form of the ribs, which are flexuous, instead of being nearly straight as in the *Ammonites* of the family of *Falciferi*, and commence at the suture instead of setting off only from its inner edge: they are also more numerous than in *G. costatus*. Moreover, the back is almost flat, and the channels slightly marked, while in the preceding species the back is round, the channels are wide, and the general form of the volutions also more rounded.

From the iron mines of Brilon; rare.

14. *Goniatites latestriatus*, nob. Tab. nost., XXVI. f. 5, 5 *a*.

Shell flattened, composed of from seven to eight half-exposed volutions, increasing slowly, and regularly rounded from the suture to the back, so that the greatest altitude is at an equal distance from both or at the middle of the side. Back round, bordered on each side by a shallow channel. Fine, simple striæ, distant from each other about a millimetre upon the last volution, set off from the suture, rise straight across half the side, then turn forward to the dorsal channel, whence they turn abruptly backward to form a deep and rounded sinus which occupies the whole width of the back. Between each of these principal striæ may be seen two or three others, extremely delicate, and which have not been expressed in the figure.

This species, of which we know neither the septa nor the siphon, resembles certain *Clymeniæ* described by Count Munster, and may indeed be related to *G. solaroides* of de Buch, which appears to be a *Clymenia*.

From the iron mines of Eibach near Dillenburg; rare.

III. Dorsal lobe divided.

A. A single lateral lobe, generally rounded, rarely sharp, and without a dorsal saddle.

While with Beyrich we place the species composing this group with those which have a truly divided dorsal lobe, we must remark, that it would perhaps be more rational to call the deep and cyathiform lobe which is on the side of the shell on each side of the back, *the lateral lobe*; the broad saddle, which spreading round over the sides occupies more than half of them, *the lateral saddle*; and to leave these species among the *Goniatites* with a simple dorsal lobe. In the latter the dorsal lobe is small and placed nearly at an intermediate height between the lower part of the lateral lobe and the summit of the lateral saddle, a disposition which may be observed in *G. Hœninghausii*. This mode of arrangement would also secure the advantage of leaving all the Goniatites with a divided lobe in the Carboniferous System.

15. *Goniatites calculiformis*, Bey., *loc. cit.*, Pl. II. f. 5.

This species, of which the volutions are almost entirely exposed, resembles *Clymeniæ* in form. Beyrich has ascertained, by the disposition of the lobes and more particularly by the presence of a dorsal lobe, that it is really a *Goniatite*; but we must add, that his figure does not express the fine and elegant striæ which are seen on the surface of that shell.

Common at Oberscheld.

B. A divided dorsal lobe; an angular lateral lobe; and a widely rounded lateral saddle.

All the *Goniatites* of this division belong to the Carboniferous system, in which there are scarcely five or six species with a simple dorsal lobe. They truly deserve the name of "*Goniatites* with a divided dorsal lobe," for the two arms of this lobe which form the beginning of the dorsal saddle and which enclose in their middle another little lobe which may be regarded as a real division of the preceding, are upon the back of the shell and may be called "dorsal lobe and saddle," while in the preceding division the lobe and the saddle called "dorsal" by Beyrich are always upon the side of the shell, and occupy more than half of it.

The common *Goniatites*, so numerous in the Carboniferous system, are very rare on the right bank of the Rhine, undoubtedly in consequence of the slight developement of the mountain limestone there. We scarcely know of any, excepting those species which are in a siliceous state, and which are found in the alluvium of the Rhur and the Rhine. These are

16. *Goniatites sphæricus*, Mart.; Petrif. Derbiensis, Pl. VII. f. 3, 4.

17. *Goniatites carbonarius*, Goldf.; de Buch, Ann. Nat. Sc., t. 29, Pl. II. f. 9.

This species is found also in the lowest beds of the coal-mines of Werden and Hoffnung in Westphalia; and appears to be very distinct from the preceding.

18. *Goniatites striatus*, Sow.; Min. Con. Pl. LIII. f. 1.

We refer to this species some impressions that are found in the slate of Bredlar in Westphalia and at Herborn. These impressions, always crushed and deformed, are nearly related in the disposition of the striæ and the form of the umbilicus to the species referred to in Mineral Conchology. The longitudinal striæ are crossed by finer and more close-set transverse striæ, forming undulations. The imperfection of the impressions, however, prevents us from fully identifying our fossil with that of the Mineral Conchology.

IV. *Goniatites* whose place is yet uncertain, the disposition of their lobes not being known.

19. *Goniatites tuberculosus*, nob. Tab. nost., XXVI. f. 4, 4 *a*, 4 *b*.

Shell flattened. Volutions six, one-third exposed, and regularly rounded from the suture to the back. These volutions are furnished with a row of rather elongated tubercles, separated by equal intervals, and placed where the side begins to turn toward the suture to form the inner edge. The surface of the shell is also covered with fine unequal transverse striæ, very close-set, which, when they come near the back appear to turn backward to form a dorsal sinus whose concavity is directed forward.

Oberscheld; very rare.

20. *Goniatites incertus*, nob. Tab. nost., XXVI. f. 6, 6 *a*.

Shell discoid, subumbilicated; volutions six or seven, one-third exposed. Inner edge almost straight, and then the surface of the volutions becomes flattened on approaching the back. Aperture ogival. Volutions furnished with twenty elongated, radiating, pliciform, rounded, not prominent

tubercles, setting off from the inner edge and becoming smaller as they approach two-thirds of the side where they disappear entirely. The whole surface of the shell is moreover covered with fine radiating striæ which become weaker as they approach the aperture.

This species is distinguished from the preceding, to which it is nearly related by the form of its back, which has a tendency to become sharp instead of being rounded, and by its much more elongated tubercles.

From the iron mines of Brilon; very rare.

21. *Goniatites tenuistriatus*, nob. Tab. nost., XXVI. f. 7, 7 *a*, 7 *b*, and 8, 8 *a*.

Shell discoid, subumbilicated, very depressed, composed of seven to eight volutions, of which the last, which is very large, constitutes alone almost the whole of the shell: it appears proportionally more enveloping than the first. Umbilicus very open, cuppel-shaped. Suture simple as far as to the last volution, where it is bordered by a slender lamellar fold surmounted by a wider and more rounded one. Back narrow and smooth at the anterior part where it is without septa. Toward the posterior fourth of the last volution the flat part of the back sinks downward slightly so as presently to form a true channel or groove with a flat bottom of a millimetre in width, neatly bounded by two little bands; this groove then continues to the apex of the spire. The surface of the volutions, except the last, is divided into two parts; that which comprises the inner edge to the suture has simple striæ, which, setting off from the latter, rise straight up to a line which bounds this first third. Against this lateral line commence finer and more close-set striæ which take a direction obliquely upwards, and soon become subdivided into three or four much more delicate and regularly undulated striæ, having the appearance of a watered stuff. These striæ then pass across the back horizontally. The lateral line which separates the two systems of striæ appears to be lost upon the last volution, as well as the second system of striæ, which becomes weaker and disappears at the same time as the dorsal groove. The second half of the last volution then only offers simple striæ which extend from the suture to the back.

The specimens which we have represented were not circular, but elongated like an *Ellipsolite*, still without presenting any appearance of malformation. A younger individual, which has been figured, and is magnified (fig. 8, 8 *a*) to show the first volutions, is perfectly regular in its form.

From the ferruginous limestone of Oberscheld; rare.

22. *Goniatites* ————

In the iron mines of Wetzlar is found a species of *Goniatite* which appears to be related to *G. retrorsus*, but the specimens we possess are too much deformed to enable us to decide. They are all elliptical and more or less depressed; the wide and rounded back is bordered by two distinct channels; and upon the sides may be observed traces of striæ, which, without being altogether parallel to the edges or longitudinal, as in *G. striatus*, Sow., are nevertheless very long, and form with the lateral channel an extremely sharp curvilinear angle.

Wetzlar on the Lahn; common.

Aptychus vetustus, nob. Tab. nost., XXVI. f. 9.

We refer to this genus a blackish impression left upon a fragment of the Eifel limestone and which is composed of two thin symmetrical subtriangular plates only presenting indistinct, undulated lines of growth with unequal spaces.

Eifel; very rare.

Although we have placed this fossil here, we do it without any pretension to determine its zoological classification.

1. *Orthoceratites regularis*, Schlot. Die Petrefact., p. 54. *O. recta*, Bosc. Conchyl.; *O. reg.*, bei Dechen Handb. der Geogn. von De la Beche, p. 535; Klöden, Die Verstein. Mark Brandenburg, pp. 131, 311; Holl. Petref., p. 235. *O. Œlandicus*, Knorr, Recueil des Monum. Tome II. Pl. II, I.* f. 8; Tome IV. Suppl., Pl. IV. *e*, f. 1–5, and Pl. V. d. f. 2; Breyn, Opuscula Pl. III. f. 1, 2, 5, 6; Bronn, Leth. geog., Pl. I. f. 10; His. Leth. Suec., Pl. IX. f. 3; Münster, Beitr. z. Petrefact., Heft iii. Pl. XVII. f. 3, 4. Variety Tab. nost. XXVII. f. 2.

Shell smooth, of a very elongated cone shape, septa very distant, horizontal, subhemispherical; siphon small, quite central and discontinuous according to Count Münster, each little tube only extending a fourth of the depth of the chamber.

Bronn says, that specimens are found which are slightly and irregularly striated transversely, and others which are smooth at the anterior part and encircled at the summit by little transverse ridges. We have observed that some individuals which present this latter character, belong to another species whose siphon is marginal.

The *O. regularis*, as may be seen by the numerous synonyms, has often been described and figured; nevertheless upon comparing the figures and the descriptions of various authors it will appear that there is still much uncertainty with regard to it, at least as to certain characters. According to Count Münster the diameter of the septa is equal to half the height of the chambers; and upon consulting his figure we find that at the anterior part the diameter is equal to the height of two chambers, while toward the summit it is only equal to two-thirds of one chamber. In the *Lethæa geognostica* the diameter of the septa is to the height of the chambers sometimes as 1 to 4, sometimes as 1 to 3, or only 2; and this last relation is not presented at the apical part, but, on the contrary, toward the middle. It is just the same with Hisinger's, where this relation is nearly as 1 to 4.

Our specimens from the slates of Wissenbach differ from these various proportions and also from all the species we are acquainted with in the great altitude of the chambers, which is at least equal to the diameter of the septa, and sometimes even beyond that, as in the specimen which we have represented. In all the other details these shells are like *O. regularis*.

The relation between the diameter of the septa and the height of the chambers appears to be a character of no importance; this proportion varies with age; and the chambers are proportionally lower as they are more distant from the summit of the shell, or as they are more newly formed. Still this relation is not exact between two shells of the same diameter which we might suppose to be of the same age: in fact we shall see in *O. triangularis* chambers of unequal altitudes alternating without any regularity.

In the same beds we meet with little parcels or bundles of acicular *Orthoceratites* from 7 to 8 millimetres in length by half a millimetre in width. These microscopic shells, which are always slightly curved, appear to be the young of the *Orthoceratites regularis*, although we have not always been able to ascertain the place of the siphon. The greater number of them are smooth, but there are some also which are finely annulated; and as it is reasonable to suppose that all the individuals of one bundle belong to the same species, of which they would be the *gemmæ*, these external differences might be thought to be characteristic of the sexes of the individuals.

Wissenbach, Œland, Elbersreuth, Schübelhammer, Prague, Revel, West Gottland; forming rolled pebbles in the Mark Brandenburgh, &c.

2. *Orthoceratites gracilis*, Blum., Arch. Telluris, Pl. II. f. 6. De la Beche, Trad. Franc., p. 556. Tab. nost., XXVII. f. 4.

Shell in form of an elongated cone. Septa numerous, horizontal, subhemispherical. Siphon small, rounded, placed at an equal distance from the centre and the edge. Toward the middle part of the shell the diameter of the septa is equal to the height of two chambers.

This species differs from the preceding in the number of its septa, which is at least double; in the

position of its siphon; and in its form being a less elongated cone. According to Count Münster it is distinguished from *O. venustus* in being less conical, and in its more marginal siphon; the siphon of *O. venustus* being nearer to the centre than to the edge. Although we have given to this shell the name of *O. gracilis*, like other authors, it is still very doubtful if it be the same as that figured by Blumenbach. In the latter the siphon is marginal, the septa are more distant, and the whole shell much more elongated, since the author says it is cylindrical and not conical.

Wissenbach; very common.

3. *Orthoceratites Wissenbachii*, nob., Tab. nost., XXVII. f. 3.

Shell elongated, cone-shaped, smooth anteriorly, annulated toward the summit by transverse ridges, more prominent and undulated as they become nearer to it. The position of these ridges is inconstant. Sometimes there is only one placed at a distance equal to two successive septa; sometimes they form two varices adjoining the suture of the septa. The latter are straight, horizontal, and slightly concave. Siphon small, round, quite marginal, and apparently continuous. Chambers numerous, shallow; two or two and a half to a diameter.

In the position of the siphon the *O. Wissenbachii* approaches to the *O. Steinhaueri* of Sowerby, from which, however, it is distinguished by its other characters. The disposition of the rings recalls to mind also the *O. duplicatus* of Münster, but this latter has the siphon central.

Var. *a*. This shell differs from the preceding in being smooth and destitute of rings throughout its length, and further because the septa are much closer, since five may be counted in the space of one diameter. As to the obliquity of the septa, in our specimens it appears to be the result of accidental compression. When this variety shall have been more fully studied, it will probably constitute a distinct species.

Wissenbach; rare.

4. *Orthoceratites striolatus*, H. v. Meyer, bei Dechen's Handb. der Geogn. von De la Beche, p. 536. *O. fragilis*, Coll. of Schl. Jahrb. f. Min. 1833, p. 483. Tab. nost., XXVII. f. 5, 5 *a*.

Shell of an acute cone shape, entirely covered with numerous filiform unequal striæ, undulated in places. Septa horizontal, near together; (two in the height of one diameter). The siphon, ill preserved in our crushed specimens, appears to be submarginal.

This species differs from the *O. cinctus* of Münster, in its more conical form, its less regular striæ, and probably also in the position of the striæ. It has some analogy with *O. cincta*, of Min. Conch., Pl. DLXXXVIII. f. 3, and *O. centralis*, of Hisinger, Leth. Suec., Tab. IX. f. 4, which, like Count Münster's, have the siphon central and the striæ equal, with very regular interspaces. Neither does the *O. striolaris* appear to us to attain the dimensions of the shells represented and described by these authors and by Phillips.

From Herborn, in the Posidonia slates; common.

5. *Orthoceratites linearis*, Münst., Beitr. z. Petref. iii. Heft, Pl. XIX. f. 1.

This species differs from the *O. cinctus* of the same author, and also from the *O. cincta* of Min. Conch., and the *O. centralis* of Hisinger, in the fineness of its striæ, which appear to be more distinct in young individuals or toward the summit of the shell.

Elbersreuth, Oberscheld; common.

6. *Orthoceratites scalaris*, Goldf., Bonn Museum.

This shell, of which we possess only an impression, and which we have seen in the same condition in the Museum of Bonn, is conoidal and very short. Its diameter increases rapidly. It is ornamented with horizontal transverse rings of which the breadth is equal to half the smooth space which separates them.

Herborn in the Posidonia slates; rare.

7. *Orthoceratites Dannenbergii*, nob., Tab. nost., XXVIII. f. 1, 1 *a*.

Shell subcylindrical, forming a very elongated cone, covered with rounded, slightly prominent, regular,

oblique striæ, crossing the suture of the septa at a very acute angle. These striæ, of which the impression is seen upon the cast itself, belong to the inner lamina of the shell, which is entirely destroyed. Edge of the septa simple. In the anterior part of the shell, which is all we possess, these septa are very close, and five may be counted in the height of one diameter. Siphon rather large, elliptical and touching the edge.

The peculiar disposition of the striæ is sufficiently characteristic of this species. It is true, the *Orthocera undulata*, Min. Conch., Tab. LIX., presents folds oblique to the axis, but they are much larger, less numerous, and inclined in the same direction as the septa. The siphon, moreover, is submarginal. In the *O. subtrochleatus* and *O. carinatus, loc. cit.*, of Münster, Taf. XIX. f. 6, 8, the siphon is submedian and median, and the folds are undulated, instead of being straight as in the *O. Dannenbergii.*

There is found in the iron mines of Brilon a transversely striated species which bears the greatest analogy with this.

It is with pleasure we dedicate this species to M. Dannenberg who has so powerfully contributed by his assiduous researches to make known the Palæontological riches of the Duchy of Nassau.

Wissenbach; rare.

8. *Orthoceratites Ibex*, Murch. Sil. Syst. Pl. V. f. 30.

This species does not appear to us to differ essentially from the *O. articulatum* (Pl. V. f. 31) of the same author, of which the ribs are perhaps more rounded, nor from the *O. annulatus* of Hisinger (Lethæa Suec., Tab. IX. f. 8), which is really the same as the *O. annulata* of Min. Conch., Tab. CXXXIII., for the obliquity of the rings is in most cases merely caused by accidental compression. It is true Mr. J. Sowerby now makes his *O. lineolatum* of this last, reserving the old name for the species called *O. annulatum* in the Sil. Syst. As to the *O. annulatum*, Phillips (Geol. Yorks., Part 2, Pl. XXI. f. 9, 10. *O. annulare*, reference to Plates), it appears to be much shorter and more conoidal than the preceding, and the *O. annulatum*, Murch. (Silur. Syst., Pl. IX. f. 5, p. 632 and note), which approaches the *O. undulatum*, Hisinger (not Min. Conch.), differs principally in its transverse festoons and its longitudinal striæ. The species which we indicate in the slates of Wissenbach is also distinguished from the *O. scalaris*, Goldf., in being much more elongated; its ridges are sharp instead of being flattened, and the spaces which separate them, more considerable.

Wissenbach; rare.

9. *Orthoceratites calamiteus*, Münst. Beiträge zur Petrefact., Heft i. Pl. XVII. f. 5. p. 36.; Heft iii. p. 102. *O. cingulatus*, Goldf., Bonn Museum.

We refer to this species, but with some doubt, in consequence of its bad state of preservation, a fragment of an *Orthoceratite* covered with transverse rings, very finely striated, as well as the intervals which separate them, and with narrow longitudinal ridges, which are more salient as they cross over the rings. Siphon median.

In consequence of the presence of the striæ, and the transverse and longitudinal ridges, this species seems to be intermediate between the *Orthoceratites* which present only one or the other of these characters.

Eifel, Chimay, Fichtelgebirge, Refrath, Brilon.

10. *Orthoceratites anguliferus*, nob., Tab. nost., XXVII. f. 6.

Shell of an elongated cone shape, smooth, but covered with *chevrons* or zigzag coloured marks, of which the acute angles correspond regularly from the upper to the lower end of the cone. These angles, about 18 in number, are alternately turned toward the summit and the base. The little brown bands which form them are half a millimetre in width, and are separated by an uncoloured space of nearly equal width. If a line be passed through the successive summits of the upper or

lower angles formed by the fracture of the same band an oblique ellipsis is obtained whose greater axis corresponds with a line passed through the siphon. Septa nearly flat and somewhat oblique. Siphon small, nearer to the centre than the edge.

This species is distinguished from all its congeners by the remarkable colours with which it is ornamented, as well as by their arrangement. This circumstance, together with several other considerations, has a tendency to prove the *Orthoceratites* to have been external and not internal shells like the *Belemnites*.

Paffrath; very rare.

11. *Orthoceratites nodulosus*, Schlot. Petrefact., Pl. XI. f. 2. Tab. nost., XXXI. f. 4, 4 *a*.

We have given a new representation of this species, as Schlotheim's figure does not clearly show the characters. It might even be taken for a different shell, for the drawing exhibits a very large siphon placed between the centre and the edge, while it is in reality central and small. Moreover the section of the shell appears to be elliptical instead of being exactly circular.

Eifel.

12. *Orthoceratites triangularis*, nob., Tab. nost., XXVII. f. 1, 1 *a*.

Shell in the form of an extremely elongated triangular pyramid, of which the section is a rectangular isosceles triangle with rounded angles, whose two smaller sides are curvilinear, but the larger or hypothenuse is straight, whence it results that the small faces of the pyramid are curved, but the large face flat. Notwithstanding the absence of the shell, there may still be observed fine, irregular, slightly prominent striæ, which upon each of the lateral faces rise toward the dorsal keel, forming with the suture of the septa an angle of 45°, and then pass over the ventral face, where they describe a curve whose convexity seems turned toward the summit. Septa triangular, rounded, concave, with slightly undulated edges, the latter turning forward a little upon each angle or keel, then turn backward again in passing over the face. Height of the chambers variable, but they are generally very low, as eighteen may be counted in a space equal to the width of one of the smaller sides. Siphon circular, rather large, placed against the middle of the larger side and opposite to the right angle of the pyramid.

This gigantic species was at least two metres in length; the fragment we possess, and which could not be figured entire, measures 0·36. We have seen at Wurzbourg, in possession of Professor Landaberger, a specimen of this *Orthoceratite*, upon which are wide, rounded, slightly raised folds, corresponding to swellings or nodosities, placed upon the principal keel: in the specimen which we have represented there are only slight indications of these folds, which must undoubtedly be more prominent toward the summit of the shell than at the anterior part, the only portion which we have.

Wissenbach; very rare.

13. *Orthoceratites subfusiformis*, Münst., Gomphoceras Beit. z. Petref., iii. Heft, Pl. XX. f. 6, 7. Tab. nost., XXVIII. f. 2, 2 *a*.

We refer to this species a shell from Oberscheld, which at least comes very near to it. Nevertheless, it is rather conoidal than ventricose; in which it resembles the *O. fusiformis* of Min. Conch., Tab. DLXXXVIII. f. 1 and 2. The shell is rather thick and covered with fine close-set striæ, turning toward the place of the siphon, which is submarginal. The presence of striæ upon this shell, which Count Münster describes as being smooth, has decided us to give a new figure of it.

Oberscheld; rare.

14. *Orthoceratites subpyriformis*, Münst., *loc. cit. supra*, Pl. XX. f. 10. Tab. nost., XXVIII. f. 3, 3 *a*.

Shell regularly pyriform, short, smooth, and rounded anteriorly. Aperture narrow, transverse, having at the ventral part a deep, symmetrical, and rounded notch. Septa straight, horizontal, numerous,

very slightly concave, placed two millimetres from each other, and not continuing quite so far as to the part where the shell acquires its greatest breadth. The remainder, as far as to the aperture, forms the last chamber. Siphon very small, round, and marginal, increasing its distance from the margin as it rises to the last septum, where it is at a distance of four millimetres.

While we preserve to this species the name of *subpyriformis*, we must remark that the chambers are only half the height of those given in the otherwise incomplete figure of Count Münster. The form, however, appears to be very variable; and the chambered part of some very inflated varieties has the aspect of the *Apiocrinite* of the Bradford clay. Among these specimens not one has shown us the folds which according to Count Münster accompany the outer margin of the upper septum and which give it the appearance of the joint of an *Equisetum*, but a very distinct notch is seen in the interior immediately above the suture of the last septum. We have observed folds similar to those in question upon individuals from the limestone of the Eifel, and it might be thought, that they had some relation to the manner in which the animal was affixed in this last chamber of its shell.

The disposition of the aperture in the present species appears to be common to all those for which the name of *Gomphoceratites* has been proposed, as well as to the *Phragmoceratites*. The *O. subpyriformis* is distinguished from *O. pyriformis* (Sow. Sil. Syst., Pl. VIII. f. 19, 20) in the position of its siphon and in the form of its aperture. This shell is naturally placed between the *Orthoceratites* and the *Phragmoceratites*.

Paffrath. It is doubtful if the shell of the Eifel and Fichtelgebirge be identical with this.

Siphon of *Orthoceratites*? Tab. nost., XXX. f. 3, 3 *a*.

We have given a representation of this which appears to us to be a cast of the annulated siphon of a very large species of *Orthoceratite*, in which case it would be placed near to the *Conotubulariæ* of Troost. In it may be seen contiguous rings divided by vertical grooves into a great number of rounded pearl-like tubercles. The section of this body shows nothing in the interior but limestone similar to the rock in which it occurs, and it is without any trace of siphonal cavity.

Paffrath; very rare.

1. *Cyrthoceratites lamellosus*, nob. Tab. nost., XXVIII. f. 4, 4 *a*, 4 *b*.

Shell conoidal, arched, depressed, covered with raised, lamellar, transverse folds, at equal distances, a little undulated and between which may be observed finer striæ, variable in number and also somewhat lamellar. These folds and striæ, passing over the dorsal region, turn back to form a scarcely evident groove above the siphon. Longitudinal, rounded, often obsolete folds are also observable toward the middle and upper part of the cone. Septa very slightly concave, elliptical. Siphon small, round, dorso-marginal. The last chamber appears to occupy one-fourth of the shell.

When the shell has been somewhat worn by friction the lamellæ disappear, and then this *Cyrthoceratite* has a very different aspect, only showing fine, very close-set, undulated, transverse striæ, which cross the longitudinal grooves. The disposition of the lamellar folds in this species brings to mind the *O. fimbriatus* (Sow. Sil. Syst., Pl. XIII. f. 20), a straight shell, whose siphon is central. In its form it approaches *O. Gesneri*, figured by Phillips (Geol. Yorks., Part 2, Pl. XXI. f. 6), of which the siphon is also submarginal, but which has no lamellar, transverse striæ. But, with regard to the *O. Gesneri* of Martin, it is a straight shell, and not a *Cyrthoceratite*. Our species differs from *C. fimbriatus* (Phil. Palæoz. Foss., Pl. XLIV. f. 214.) in the greater number and less depth of its longitudinal furrows, by its transverse lamellæ being much more serrated, and by its general form being less bent. It differs equally from the *C. quindecimale* of the same author (Ib., Pl. XLIV. f. 216.) by its less serrated lamellæ and its less marked longitudinal furrows.

As the *Orthoceratites subpyriformis* or *Gomphoceratites* approaches the *Phragmoceratites*, so does the

Cyrthoceratites lamellosus seem to unite the *Cyrthoceratites* to the *Orthoceratites*. These two last-named genera are furthermore very nearly related, if indeed one of them ought not to be regarded as a subgenus. The *Orthoceratites* are straight in the adult state, but when young the greater number are a little curved, and further we find, according to the species, that the place of the siphon varies from the centre to the margin. If, on the other hand, the character of the *Cyrthoceratites* is to be curved and involute, and to have the siphon dorsal, an uninterrupted series might be formed from the entirely involute *Cyrthoceratites* of the mountain limestone of Tournay, to those which are nearly straight, and that including the form proper to the *Spirula*.

As to the position of the siphon, it is also subject to great variation; thus, the *Cyrthoceratites aigoceros* (Münster Beiträge, &c., 1839, Pl. II. f. 1.) has the siphon median. In the *C. cincta* of the same author (Pl. II. f. 4.) it is also median, but in the *C. costata* (f. 5.) it is subventral. Then our *C. lamellosus* presents nearly the same degree of curvature as the *C. cincta* and the *C. costata*, nevertheless its siphon is neither central nor ventral, but dorsal. The boundary between these two genera is not well-marked, and it does not appear that it ought to be continued, except to facilitate the study and the classification of the numerous species which belong to them. In a methodical classification we think that the *Cyrthoceratites*, the *Phragmoceratites*, the *Gomphoceratites*, the *Actinoceratites*, the *Conoceratites*, the *Ormoceratites*, the *Conotubulariæ*, &c., ought to form only subdivisions of the great genus *Orthoceratites*.

Paffrath; common.

2. *Cyrthoceratites ornatus*, Goldf., Bonn Museum. Tab. nost., XXVIII. f. 5, 5 *a*, 5 *b*. Phil. Pal. Foss., Pl. XLV. f. 217.

Shell involute, spire formed of at least one volution and a half, depressed perpendicularly in the direction of the involution and increasing rapidly in width. Surface of the shell divided into two parts or regions, one ventral, the other dorsal. The ventral or internal region presents nine or ten longitudinal slight folds, sometimes bifid and separated by equal intervals. These folds, which are more apparent near the aperture than toward the summit, are crossed by fine, close-set, unequal, undulated and slightly lamellar striæ of growth. The dorsal region is furnished with three longitudinal rows of elevated tubercles which are geminated or united together in pairs. The tubercles of the median row are placed a little behind those of the lateral rows, they are also less elevated, a little elongated and arranged in a zigzag direction. In each pair placed on the side, the tubercle which occupies the lateral keel is larger and more prominent than that of the back, to which it is joined by a sort of pinching up of the shell. This last is sometimes divided into two by longitudinal folds similar to those of the ventral region, and of which five or six are counted on each side of the back. It is the passage of these folds over the little transverse ridges which appears to produce the tubercles. This part of the shell is also covered with close-set, lamellar, undulated lines of growth. Septa slightly concave, irregularly elliptical. The difference between the two diameters augments gradually with age. Toward the summit of the shell this difference is as 3 to 4 and almost as 1 to 2 for the last septum. Siphon dorsal, submarginal, and corresponding to the interval between the median tubercles.

The form of the septa, the position of the siphon, and the striæ of growth, approximate this fine species to the preceding; but it differs much in its stature, in its tubercles, and in the involution of its spiral cone.

Paffrath, Eifel; rare. Newton, Devonshire.

3. *Cyrthoceratites Eifelensis*, nob., Tab. nost., XXXI. f. 2, 2 *a*, 2 *b*.

Shell involute, formed of at least one volution and a half, depressed perpendicularly in the direction of its involution and increasing rapidly in width. Surface of the shell divided into two parts or re-

gions, the one ventral, the other dorsal. The internal or ventral region presents from twelve to fourteen longitudinal folds or threads, with pretty equal spaces. Transverse folds, arched from back to front, with wider spaces than the threads, pass over these latter and form little tubercles upon them. Dorsal region more ventricose than the preceding, from which it is separated by two lateral keels. On each side of the back may be reckoned seven rounded folds or threads, more prominent than those of the ventral region. Transverse folds, setting off from the lateral angles, where they join those of the inner part by a very salient tubercular pinching (*pincement*), turn back, forming a very elongated S, and describe upon the middle of the back a sinus whose concavity is turned forward. The passage of these folds over the longitudinal folds is also marked by a more or less distinct tubercle. The whole shell is covered with fine, close-set, transverse undulated striæ, which turn abruptly backward, passing over the back. Aperture transverse, ellipsoidal. Siphon unknown, but probably subdorsal.

In young specimens (fig. 2 *b.*) the threads, as well as the transverse folds, are less prominent and rounded, and are destitute of the tubercle at their point of union.

The *C. Eifelensis* differs from the *C. ornatus* in its more numerous threads and in the transverse folds of the dorsal region which are more close-set and continuous, instead of being interrupted. It has fourteen almost equal tubercles upon each fold, while in the *C. ornatus* there are only six, united two by two or in pairs. These two shells are in other respects very nearly related, and it may not be impossible to unite them as varieties when we shall have compared a sufficient number of individuals. At the same time it must be remarked that the characters which have determined us to distinguish them are observable in all stages of growth of each shell. These two species are likewise distinct from the *Spirula nodosa* of Bronn and of the Bonn Museum.

The *C. Eifelensis* is apparently allied to the *C. tredecimale* (Phil. Pal. Foss., Pl. XLIV. f. 215.), but the state of the specimen figured by that author does not permit us to establish a perfect identity between the two shells. Moreover, the *C. Eifelensis* has fourteen longitudinal ribs instead of thirteen, and the latter number being unequal presents a rare circumstance in these symmetrical shells, the middle of the back of which is usually occupied by a more or less marked furrow. Besides, the transverse striæ are filiform and very close, instead of being only four between each transverse rib. Finally, the latter are more numerous than in the shells from Devonshire.

Eifel; rare.

4. *Cyrthoceratites depressus* (*Cyrtocera depressa*), Goldf. Bronn, Leth. geog. Pl. 1. f. 5. Tab. nost. XXIX. f. 1, 1 *a*.

Shell in form of a shortened (surbaissé) cone, arched and forming half a volution, ventricose and obliquely depressed at its anterior part. Shell very thick upon the sides, thinner upon the back, marked with fine close-set lines of growth, rising over the back where they cross the suture of the septa at an angle which increases in proportion as these latter are nearer to the aperture. Septa nearly flat, in form of a horse-shoe, very rounded toward the summit of the shell, becoming elongated toward the middle part and presenting near the aperture three-fourths of an ellipsis, the last fourth of which is occupied by a ventral truncation. This truncation, which diminishes in width from the aperture to the summit of the shell, offers throughout this extent three slight undulations, of which one is median and two lateral. This disposition of the septa, which seem to radiate from a point taken at the interior of the ventral curve, agrees with the height of the chambers which is four times greater upon the back than upon the ventral part. Siphon subdorsal, occupied by a bundle of radiating or polypiform fibres, owing undoubtedly to a particular disposition of the muscle of attachment.

The specimen, which we have figured of its natural size, is very like that which is represented, reduced

to a third, in the *Lethæa geognostica* (*loc. cit. supra*); but, besides this latter figure not giving any idea of the remarkable disposition of the septa, it is otherwise inexact in the height of the chambers on the ventral part, not having been diminished proportionally to the rest of the shell, appearing double their proper height.

Var. *a*. Shell distinguished from the preceding by a distinct, central, dorsal keel, which gives a pentagonal form to the septa.

We must observe, that it is to the unequal increase of the opposite edges of the chambers that the shells of this group owe the obliquity of their septa, and consequently their curved form, which, as may easily be conceived, is so much the stronger as the inequality is greater. Completely involute shells, like the *Goniatites*, show this difference at its maximum. Nevertheless, in the *Cyrthoceratites depressus* this curvature is relatively slight; but this arises from the circumstance, that to the preceding differences in the height of the same chamber, there is added a much more distinct compression toward the aperture than toward the summit, and at the same time a rapid increase in the diameter of the shell.

Eifel; rare.

5. *Cyrthoceratites lineatus*, Goldf., Bonn Museum. Tab. nost., XXX. f. 2, 2 *a*.

Shell conoidal, short, very slightly arched, very thick, marked externally with irregular, simple, sinuous lines of growth, which turn backward and pass above the siphon. The internal lamina of this shell presents longitudinal folds on each side of the back, which are often obsolete, but still distinct enough. A broad shallow depression is to be observed in the middle of the concave part opposite to the siphon. Septa nearly flat, suborbicular and horizontal toward the summit, ellipsoidal and oblique as they approach the aperture. Upon the back the chambers are twice and a half the height they are on the ventral side. Siphon round, nine millimetres in diameter, and placed ten millimetres from the dorsal or convex margin of the shell.

Paffrath, Eifel; rare,

6. *Cyrthoceratites tetragonus*, nob. *Spirula dorsata*, Bonn Museum. Tab. nost., XXXI. f. 3, 3 *a*.

Shell quadrangular, slightly arched, presenting longitudinal tubercular folds, with equal interspaces, upon the two outer angles. Inner angles simple. Septa numerous, near together, with undulated edges, concave on each surface and rising toward the aperture at their passage over the angles. Siphon small, subdorsal. Shell smooth or only marked with striæ of growth.

Eifel; rare.

Phragmoceratites subventricosus, nob. *Cyrthoceratites compressus*, Goldf., Bonn Museum, Tab. nost., XXX. f. 1, 1 *a*.

Shell in the form of a slightly elevated cone, compressed upon the sides and slightly arched, so as to present only half a volution when the shell is complete. Septa slightly concave, elliptical, having their greater diameter between the back and the ventral part, and being also a little sinuous anteriorly on the dorsal region. Chambers two and three times higher dorsally than ventrally. Siphon ventral, very near the edge, and madreporiform.

This shell differs from the preceding in the position of the siphon, which is ventral, or placed on the concave face, and in its compression, which is parallel to its curve, instead of being perpendicular to it. These two characters, if constant, would justify the subdivision established under the name of *Phragmoceratites*. Our species, however, is distinguished from *Phr. ventricosus* (Broderip, Sil. Syst., Pl. X. f. 4—6) in being less compressed, which renders its two diameters less unequal. This difference accords with that of its geological position; Mr. Murchison's species being found in Norway, as in England, in the Silurian System, while ours belongs to the Devonian System.

Eifel, Refrath; rare.

1. *Conularia Gervillei*, nob. Tab. nost., XXIX. f. 3 and 4, 4 *a*, 4 *b*, 4 *c*.

Shell straight, forming a very compressed quadrangular pyramid, with equal sides and rounded angles.

Angles occupied by a deepish channel. A central, longitudinal depression upon each face. Fine, regular, equal, close-set striæ cover the whole shell. They turn back abruptly at their passage over the lateral channel, at the bottom of which they are less distinct; and they produce a simple undulation where they traverse the central depression of each face.

We regard this specimen, which comes from Kemmenau near Ems, as the cast of the posterior part of a species which we have found at Néhou (La Manche). This last, which we have also represented (at f. 4), shows, upon the preserved part of the shell, little transverse ridges formed of rows of very fine and very regular granulations, separated by smooth grooves (f. 4 *b*). These granulations have been more or less destroyed by rubbing, and they are then represented by small irregular pores, also placed in rows (f. 4 *c*). And lastly, in those parts from which the shell has completely disappeared, the striæ observed upon the cast are similar to those on the specimen from Kemmenau. As to its flattened form, we think it is the same now as it was originally, and that it is not the result of compression after the death of the animal. It may be admitted that there have been *Conulariæ* of different forms, as there are among the *Hyalææ* and *Cleodoræ* of the present seas.

The specimens represented by figs. 3, 5 and 6, Pl. CCXL. of the Mineral Conchology, come pretty near to our species. In fact, they differ, says Mr. Sowerby, from that represented by f. 4, the only one which has served to establish the characters of the *C. quadrisulcata*; but we should be disposed to think them still nearer to that figured at Pl. XII. f. 22. of the 'Silurian System,' to which we preserve the name given by Defrance, not believing it to be the same as the *C. quadrisulcata* from Coalbrook Dale. This opinion appears to us to be further confirmed by that of J. Sowerby himself, and it also agrees with the difference of geological position.

From the Grauwacke of Kemmenau; Néhou (La Manche, France); rare.

2. *Conularia ornata*, nob., Tab. nost., XXIX. f. 5, 5 *a*.

Shell pyramidal, rectangular, consisting of four equal faces with a longitudinal channel on each angle. Faces slightly convex, ornamented with oblique, equal, regular folds, finely plicated at their summit and disposed in very open zigzags. On the middle of the faces, the folds diminish to overlay each other in an alternately inclined manner, instead of continuing from one edge to the other. The row of this sort of anastomosing folds, forms a longitudinal central elevation, though not very distinctly marked. The folds reach to the edge of the corners, alternating and terminating at the base of the channel with one or two small granulations. The transverse grooves which separate the folds are perfectly smooth.

This species is distinguished from *C. quadrisulcata* (Min. Conch. Pl. CCXL. f. 4. and Geol. Trans., vol. v. Pl. XL. f. 2. *Non id.* Sil. Syst., Pl. XII. f. 22.) in having wider folds with wider spaces, and in the smoothness of the grooves which separate them.

Refrath, Eifel; rare.

3. *Conularia Gerolsteinensis*, nob., Tab. nost., XXXI. f. 5, 5 *a*.

Shell in form of a quadrangular pyramid, with a compressed, rhomboidal base. Surface rather irregular, covered with transverse, capillary, very close-set, granular striæ. These striæ, whose convexity is toward the aperture, become more and more arched as they approach the summit, and they correspond to the bottom of the grooves which follow the angles of the pyramid.

The extreme tenuity of the striæ of this *Conularia* distinguishes it sufficiently from its congeners. Judging from an impression which comes from the same beds, this shell was prolonged at its summit into a recurved point, and it appeared to terminate anteriorly in part of a rounded vault.

Eifel; rare.

There is found in the limestone of Néhou a *Conularia*, *C. Brongniarti*, nob., (Tab. nost., XXXI. f. 6, 6 *a*, 6 *b*.) which is of a similar compressed form with the *Conularia Gervillei*, but it is distinguished

from that, as well as from the *C. ornata*, in having its pretty distinct folds continuous throughout the breadth of the faces; in their meeting upon the margins of the angles without uniting; and in the transverse grooves being covered with very fine, very regular, very close-set perpendicular striæ, which are only perceived with a magnifying glass. They differ also decidedly from the little folds which are observable upon certain varieties of the *C. quadrisulcata*. The upper part of the shell is rounded into a vaulted form, and the ribs are granular and more close-set than upon the middle of the faces. To avoid all confusion relative to this species, we have given a figure of it.

The *Conulariæ*, of which we now know ten species, are found in all the strata below the coal, and even in the coal beds, but it is easy to see that the species of this genus have been but ill determined down to the present time, or rather that they have all been referred to the *C. quadrisulcata* of the Mineral Conchology, and because characters which belonged to the genus have been regarded as specific. It is only needful to compare the figures given by Bronn (Leth. Geog. Taf. I. f. 12.) and Hisinger (Leth. Suec. Tab. X. f. 4.) with those in the Mineral Conchology (Tab. CCLX.) to ascertain that they cannot all belong to one species. The figure in *Lethæa Geognostica* represents the *C. pyramidata* of May (Calvados), where it is common. A second, rectangular, more elongated species, covered with extremely fine striæ, is found, but very rarely in the same locality. The *Conularia* of Sweden appears to belong also to the *C. pyramidata*. And lastly, we know still another small species from St. Petersburgh, and one from North America.

We have not been able to recognize in any of the specimens which we have examined, the two siphon-like depressions mentioned by J. Sowerby (Sil. Syst. p. 627), and we think, the family to which it seems these shells ought to be referred, precludes the idea of the existence of such a character.

1. *Bellerophon striatus*, de Fer. et d'Orb. Monograph. des Cephal., Pl. VII. f. 6, 7. (*non* Sow. Sil. Syst.; *non* Bron. Leth. Geog., *non* Phil. Pal. Fos.), *B. undulatus*, Goldf. Bonn Museum, Tab. nost. XXVIII. f. 6.

Shell nautiloid, globular, umbilicated; umbilicus small and deep. Aperture very large, transversely dilated, arched and semilunar. Shell thick, covered with transverse, rugose, pliciform and undulated striæ, converging on one side toward the umbilicus, and terminating on the other at a central keel near to which they turn backward. The folds are wider and more prominent as they approach the aperture. The keel is flattened and formed by striæ of growth of which the concavity is turned toward the aperture. These striæ indicate the successive formation of the notch which corresponds to the middle of the right lip.

M. d'Orbigny regards this species as identical with the *B. undulatus* of Goldfuss.

Paffrath; rare.

2. *Bellerophon tuberculatus*, de Fer. et d'Orb., *loc. cit. supra*, Pl. VIII. f. 7–10. Tab. nost. XXVIII. f. 9.

Shell very globular; aperture transverse. The shell covered with fine and regular granulations interrupted upon the central keel.

We have met with only very incomplete specimens of this species.

Eifel; Paffrath.

3. *Bellerophon Murchisoni*, de Fer. et d'Orb., *loc. cit. supra*, Pl. VII. f. 1, 2, 3. (*B. striatus*, Sow. Sil. Syst. Pl. III. f. 12. *e.*) Tab. nost. XXVIII. f. 7, 7 *a*, 7 *b*. Var. fig. 8.

We have represented this shell, which is already figured in Murchison's work under the name of *B. striatus*, because it is a species common to the Devonian and the Silurian systems, being found not only in the old red sandstone of England, but also in the slates of Wissenbach, which represent the upper part of the Silurian system on the banks of the Rhine.

The variety, fig. 8, is distinguished by its more distinct keel. The back does not show any flattened

central part. The aperture has the form of a complete instead of a truncated ogive, and striæ like those of the typical variety are not perceptible.

Wissenbach.

4. *Bellerophon elegans*, de Fer. et d'Orb., Pl. VII. f. 15–18. Tab. nost., XXIX. f. 2. 2 *a*.

Shell globular, nautiloid, entirely covered with fine, longitudinal, pretty regular striæ decussated by less prominent transverse striæ, which turn backward slightly, passing over a scarcely evident central varix striated like the rest of the shell. Aperture large, rounded. Left lip reflected upon the two sides of the last turn but one of the spire and partly masking a very small umbilicus.

Paffrath; rare.

Rostellaria ——— ?

We refer to this genus, not unhesitatingly, an impression which we found in the Grauwacke of Prüm in the Eifel.

1. *Buccinum arculatum*, nob. *Buccinites arculatus*, Schlot. Pl. XIII. f. 1. Tab. nost., XXXII. f. 1.

We unite under the name of *Buccinum arculatum* several shells different enough at first sight, of which a figure given by Schlotheim may be regarded as the principal type.

The last volution being very much inflated at the base, gives the shell a regular conoidal form. The volutions are bounded above by a very broad area, generally flat, sometimes slightly concave or even convex. This area is bounded externally by a more or less distinct, rounded varix which accompanies it to the top of the spire. The volutions are flattened or very slightly convex. In the elongated variety a depression is seen below the varix, which is more rounded, the area is contracted and has a tendency to disappear. In the most inflated variety, which we have figured, the first volutions are ornamented with small, longitudinal folds, inflected toward the middle, and pretty regularly oblique toward the axis. Upon the last volution, these folds have only the character of striæ of growth. On the contrary, in the very elongated specimens they are less regular upon the first volutions, and the whole shell only presents lines of growth. The different varieties show upon the middle part of the volutions four or five obsolete, transverse, undulated grooves parallel to the suture. The aperture little, slightly truncated, and effuse at the base, is rather narrow. The left lip is covered with a callosity which rises to the upper angle and hides a very small umbilicus, and then spreads over its lower extremity without forming a distinct canal. Columella wide, flattened, and furnished at its base with a more or less distinct fold. Right lip sharp-edged, simple, slightly sinuous and oblique to the axis. Upper angle sharp, but widened by the extension of the varix.

Altitude of the variety figured, 93 millim. Diameter of the last volution, 53 millim.

Paffrath; very common.

2. *Buccinum Schlotheimii*, nob. *Buccinites subcostatus*, Schlot. Pl. XII. f. 3. *Macrocheilus arculatus*, Phil. Pal. Fos., Pl. LX. f. 194*. Tab. nost., Pl. XXXII. f. 2.

Shell turriculated, mucronated at the summit, more or less inflated toward its medio-inferior part and contracted at the base, composed of nine volutions, of which the first are covered with fine, longitudinal, rather oblique, undulated and pretty regular folds, while the last usually present only lines of growth. Suture simple, deepish. Aperture narrow, very contracted at its upper angle, a little dilated and rounded at its base. The truncation is scarcely evident. Left lip covered to the top by a wide callosity, rarely well-preserved. Columella very much flattened, offering in some individuals two rather distinct folds which are confounded at the base by a very short rounded one.

Height of the largest specimens, 137 millim.; diameter of the last volution, 50.

This species is not less variable than the preceding, and we might even say that it is connected with it by intermediate forms which would have determined us to unite them if we had not found some charac-

ters constant enough to separate them. In fact, the *B. Schlotheimii* is always more elongated than the *B. arculatum*, particularly the latter volutions, and it is contracted at the base. The simple suture is not accompanied by an area nor a varix. The less conoidal shell, which is mucronated and often inflated toward its middle part, resembles certain Mitres. The aperture also differs from that of *B. arculatum*. The system of folds upon the first volutions, and lines of growth on the last, are, on the contrary, perfectly similar in the two species.

We refer the *Buccinites subcostatus* of Schlotheim to the *B. Schlotheimii*: it is an inflated variety of it, as is also the *Phasianella ventricosa* of the Museum of Bonn. We have not preserved to it the name of *subcostatus*, because that would seem to point out as a distinguishing character the only one that is precisely common to both species. We refer to this species, also, as a variety, an elongated and more regularly conoidal shell, of which the upper part of the volutions, which is concave, is covered with transverse striæ, which in crossing over very fine longitudinal folds form an elegant net-work upon that part of the spire.

Bronn unites to these two species the *B. breve* and *B. imbricatum*, Min. Conch., Tab. DLXVI. f. 3, 2, but it is undoubtedly of the *B. acutum* (*Ibid.* f. 1.) that he intended to speak, as the *B. breve* has not the least relation to *B. arculatum*. There are, however, so many species whose forms are nearly similar, that it is difficult to make even tolerably certain approximations from mere figures. Thus the *B. imbricatum* would be referable to the variety ticketed with the name of *Phasianella ventricosa* in the Museum of Bonn. The figures 9, 17, 18, 19, and 20 of plate XVI. of Phillips (Geol. of Yorks., Part II.) might also be referred to *B. Schlotheimii*, but the last volution is proportionally much higher than in any of our varieties; and the same with the aperture. As to the *B. acutum* of Mineral Conchology, it is certainly very near to our species, but the figure given by Phillips seems to represent altogether a distinct shell.

Paffrath; very common.

3. *Buccinum breve* (variety), Sow. Min. Conch., Pl. DLXVI. f. 3.

We regard as a mere variety of *B. breve* a shell which differs only in its spire, in which there are two more volutions, and in the elongation of its last volution which renders the shell less globular and longer than that of the Mineral Conchology. The absence of a notch at the lower edge of the aperture, inclines us also to Mr. Sowerby's opinion, that this shell would be better placed with the Turbines.

Paffrath; rare. Limestones of Devonshire.

MURCHISONIA.

Generic character. Shell turriculated, aperture oblong, oblique, terminated at its base by a very short canal. Columella arculated and slightly recurved outwards. A narrow, more or less deep fissure on the right lip, with parallel edges, the successive filling up of which produces a single or double keel upon the middle of the volutions, or a narrow continuous band, exactly circumscribed throughout the whole height of the spire†.

1. *Murchisonia coronata*, nob. *Turritella spinosa*, Goldf. Bonn Mus. *Cerithium antiquum*, Stein., Mém. de la Soc. Géol. de France, t. i. p. 367. Tab. nost., XXXII. f. 3.

Shell turriculated, pointed at the summit, with ten or twelve convex volutions. Suture deep, edged beneath with very salient, rather oblique tubercles, ten to each volution, and which are more elevated than the middle keel. The latter is edged by two threads or narrow ridges. The striæ of

† For the details relative to the establishment of this genus and its species, see Bulletin de la Soc. Géol. de France, t. xii. p. 154. 1841.

growth turn abruptly backward as they approach the middle keel, and then forward again after having crossed it. Upon the base of the last volution they are arched and converge toward the extremity of the canal which terminates it. A granular cord parallel to the keel may be seen also at the base of this last volution. Aperture elongated, rounded in the middle. Columellar lip covered with a narrow callosity which extends from the upper angle to the base of the aperture. Canal very short. Right lip furnished in the middle with a narrow and deep notch corresponding to the keel. Height, 35 millim; diameter of the last volution, 13.

We had at first referred to this species (Bull. de la Soc. Géol. de France, t. xii. p. 154) the *Buccinum spinosum*, Min. Conch., Tab. DLXVI. f. 4, but Mr. J. Sowerby's figures 24–27 of plate LVII. of the 'Memoir' of Sedgwick and Murchison (Geol. Trans., vol. v.), and those of *Murch. spinosa* (Phil. Pal. Fos., Pl. XXXIX. f. 192), have led us to consider the Devonshire shell as different from those which we describe, as well in the form of the mouth as of the tubercle on the last whorl. We have named the shell from the banks of the Rhine *M. coronata*, which appears to have been given by Goldfuss to one of his varieties, and which we found quoted in the Memoir of Beyrich (Beiträge, &c., p. 15).

Found in all the *Strygocephalus limestones* of the banks of the Rhine, Paffrath, Hagen, Iserlohn Villmar, Sötenich, &c.; very common.

Var. *a*. Shell conoidal, very much shortened; tubercles smaller, more numerous and less oblique.

From the same localities.

2. *Murchisonia intermedia*, nob., Tab. nost., XXXII. f. 4. Var. *a*, f. 5.

Shell turriculated, pointed at the summit, composed of eight or nine convex volutions. Suture deep, accompanied by a decurrent granular varix, less elevated than the keel. The latter is scarcely salient, but well marked by two parallel threads. Striæ of growth disposed as in the preceding species. Aperture oval, contracted at its extremities. Columellar lip covered with a callosity which hides a very small umbilicus and rises again to the upper angle of the aperture. Columella rather twisted, recurved in form of an S. Canal very short and not deep. Right lip thin, sharp-edged, furnished with a narrow and deep notch which corresponds with the keel. Height, 35 millim.; diameter of the last volution, 13.

Var. *a*. f. 5. Tubercles slightly marked, often blended together and then forming a continuous varix. Keel salient, more elevated than the varix. The granular ridge at the base of the last volution is scarcely distinct. Shell more elongated than the preceding, and of which the volutions appear to be imbricated. Height, 42 millim.; diameter of the last volution, 15.

Var. *b*. Shell very short, conical and resembling a little Trochus.

Paffrath; common, with the preceding.

3. *Murchisonia angulata*, Phil. Pal. Fos., Pl. XXXIX. fig. 189. *Rostellaria*, id. Geol. of Yorks., Part II., Pl. XVI. fig. 16. Tab. nost., XXXII. f. 6. Var. *a*, f. 7.

Shell conoidal, volutions increasing rapidly, very excavated. Varix not strongly marked. Keel elevated, double, angular, channeled. Suture very deep. Lines of growth similar to those of the preceding; aperture rounded and not so high. Height, 42 millim.; diameter of the last volution, 21.

Var. *a*. f. 7. Shell more elongated than the typical variety. Varix none. Keel elevated, sharp-edged, single to the summit, where nothing is perceived representing the channel of the other variety. A second, less evident keel, on the base of the last volution.

Paffrath; with the preceding, common. Petherwin (Cornwall), Brushford (North Devon). Paffrath, Visé (Belgium), in the mountain limestone. Bolland, *ibid.*

4. *Murchisonia bilineata*, nob. (*non* Phil. Pal. Fos.) *Turritella bilineata*, Goldf. Bonn Mus. *Melania*, *id. ib.*, Tab. nost., XXXII. f. 8.

Shell usually rather short, mucronated at the summit, and inflated toward the middle. Volutions slightly convex, rounded or slightly flattened. Varix very slight, sometimes none. Keel scarcely visible, but always indicated by the two threads which accompany it. Striæ of growth similar to those of the preceding species. Base of the last volution simple. Aperture oblong, oblique, contracted at its extremity. Columellar lip covered with a callosity which rises to the upper angle of the aperture, where it is united to the right lip, forming a little channel within. Columella twisted, recurved in the form of an elongated S. Canal short and very shallow. Right lip thin, furnished with a deep slit which corresponds to the keel. Height, 39 millim.; diameter of the last volution, 17.

Var. *a*. Shell shorter and conoidal.

Paffrath &c.; with the preceding, common. Gronau.

There is found in the limestone of Néhou (La Manche) a second, more slender variety, with rounded and very convex volutions. We have also collected it at Izé, near Vitré (Dép. de l'Île et Vilaine).

The four species which we have just described are connected together by numerous varieties, and characterize the principal type that we have distinguished. We have rather proposed to facilitate the study and the knowledge of these numerous shells, than to establish among them really distinct species.

5. *Murchisonia bigranulosa*, nob., Tab. nost., XXXII. f. 9. Var. *a*, f. 10. *M. bilineata*, Phil. Pal. Foss., XXXIX. f. 191. Var. *b*, f. 11.

Shell conoidal, turriculated, composed of from ten to twelve flattened volutions. Keel salient, forming a little band divided by a more or less distinct line and occupying the middle of the volutions. Two rows of granulations accompany the suture, the one above, the other below. Upon each volution the elongated and ovoid granulations of the upper row, sixteen or seventeen in number, are double the size of those of the inferior row. Suture deep and channeled. Base of the last volution (in the variety *b*, fig. 11), covered with granular lines formed by the crossing of the transverse striæ and folds which radiate from the base of the left lip: these latter end at the inferior row of tubercles. Lines of growth, moreover, cover the whole shell. They turn abruptly backward as they approach the keel, and then forward again when they have crossed over it. Aperture elongated, contracted at its extremity. Left lip nearly straight. Columella a little elongated. Canal very short, at the union of the two lips. Right lip furnished with a pretty deep slit, the successive filling up of which during the growth of the shell is marked by the median keel.

Height, 80 millim.; diameter of the last volution, 24.

Var. *a*. Shell shorter and more conoidal than the preceding. On the last volution the lower row of granulations is sometimes represented by a ridge or a simple keel, and then the upper volutions have only a single row of granulations. We refer to this variety the *Turritella abbreviata* (Min. Conch., Pl. DLXV. f. 2. Syn. *Murch. bilineata*, Phill. Pal. Fos., Pl. XXXIX. f. 191), which, according to the author, has two rows of granulations upon each volution. In our opinion, therefore, Bronn was mistaken in referring it to one of our preceding species. Still, it must be acknowledged that this variety is very near to the abbreviated variety of *M. coronata*, although there is a great difference between the extremities of these two species.

Paffrath; very rare. Devonshire, for the variety *a*.

6. *Murchisonia binodosa*, nob., Tab. nost., XXXII. f. 12.

Shell conoidal, subturriculated, composed of from eight to ten deeply excavated volutions. A rather wide, very flat, but neatly limited little band occupies the centre of each volution. Two rows of tubercles accompany the suture. The tubercles of the upper row, sixteen in number, are very salient and rounded. Those of the lower row, on the contrary, are but slightly evident, being well seen only on the last volutions. Lines of growth fine and undulated, turning backward as they ap-

proach the fissure, and forward again after passing it. The little band presents arcuated striæ, whose concavity is turned forward. Slightly undulated folds, granular at their commencement, are seen upon the base of the last volution. Aperture oblong, differing probably but little from those of the preceding species.

This shell differs from the *M. bigranulosa*, by its much greater stature, by the size of its tubercles and the form of its volutions which are excavated instead of being flat; and lastly, by its broad and flat band, which is narrow and raised in the preceding species.

Lustheide; very rare.

7. *Murchisonia tricincta*, nob. *Schizostoma tricincta*, Münst., Beitr. z. Petref., iii. Heft, Pl. XV. f. 14. Var. Tab. nost. XXXII. f. 13, 13 *a*.

This shell differs from that figured by Count Münster, in the keel being placed near the base of each volution, instead of dividing them into two equal parts; thus the volutions are, as it were, imbricated. Further, there is between the keel, which is double, and the suture, a third thread, which is not seen in the type of the species; and lastly, our shell appears to attain a much greater dimension than that of the limestones of Elbersreuth.

Villmar; very rare.

8. *Murchisonia tæniata*, nob. *Turritella tæniata*, Phill. Geol. of Yorksh., Part 2. Pl. XVI. f. 7.

We have some doubt in referring to this species, belonging to the mountain limestone of Bolland, a worn-out shell brought from Gronau.

Turritella ——— ?

To this genus we refer a not well-characterized cast of a shell which we found in the slates of Wissenbach.

Turbo squamiferus, nob., Tab. nost., XXXII. f. 14, 14 *a*.

Shell conoidal, subturriculated, composed of six angular volutions each ornamented with two rows of raised pliciform scales, one of which, very prominent, is on the medio-superior part of the volutions, and the other, which is composed of finer and more numerous scales, is at the base. Suture simple. Two narrow and sharp keels are also seen at the lower part of each volution; one of these, frequently plicated, forms the outer edge of a very small umbilicus, and ends at the base of the right lip. The whole shell is covered with lines of growth, more distinct on the last volutions than on the first. Aperture round, its edges disjoined at the upper part. Left lip a little reflected, and uniting with the right lip by a continuous curve. Height, 28 millim.; diam. of the last volution, 20.

Limburg.

Monodonta purpurea, nob., Tab. nost., XXXII. f. 15, 15 *a*.

Shell trochiform, composed of four volutions, of which the last is very large and constitutes alone two-thirds of the shell. Volutions convex, rounded, covered with from ten to twelve rows of granulations, disposed very regularly and reaching to the umbilical callosity, near to which the striæ are finer and more close-set than upon the last volution. Aperture semilunar, very oblique to the axis. Left lip wide, very much flattened, and entirely covered by a callosity which rises to the upper angle. This lip is furnished with a rather strong tooth placed at the top of the umbilicus. The latter is hidden by the callosity, but a slight depression points out its place. Columella arcuated and united to the right lip by a regularly rounded curve. Height, 22 millim.; diameter of the last volution, 18.

This shell is remarkable for the flattening of the left lip, very like what is observed in the *Purpuræ*, and for the absence of any truncation of the columella, which is united continuously with both lips. It could be referred to Grateloup's genus *Neritopsis*.

Paffrath; rare.

Trochus Ivanii, Lev., Mém. de la Soc. Géol. de France, t. ii. Pl. II. f. 24. Var. Tab. nost., XXXII. f. 16.

We have represented this variety, which we should have regarded as a distinct species, if intermediate forms had not obliged us to refer it to the *Tr. Ivanii* from Tournay, which is itself extremely variable in that locality. Our variety is much more depressed than the type of the species and the rounded volutions scarcely present a rudiment of the area and the keel. The striæ are more unequal and at less regular distances: the base of the shell also is less inflated and the aperture is more rounded.

Paffrath; rare. Tournay (Belgium), in the mountain limestone.

1. *Pleurotomaria catenulata*, nob., Tab. nost., XXXII. f. 17, 17 *a*.

Shell in the form of an abbreviated cone, composed of four convex volutions flattened on the upper part. Suture simple. Volutions ornamented with six or seven granular threads, of which the two central are the largest and form a distinct angle upon that part of the spire. The space between these two threads is occupied by concave striæ representing the fissure of the right lip. Base of the last volution wide, convex, covered with very numerous and very regular concentric striæ, between which there is often one very fine intermediate. Umbilicus very small. Aperture transverse. Left lip slightly arcuated. Columella salient. Inferior edge parallel to the superior. Right lip rather angular toward the middle part where the notch is.

This species is apparently allied to *P. aspera* (J. Sow., Geol. Trans., Second Series, Vol. V. Pl. LIV. f. 16.; Phill. Pal. Foss. XXXVII. f. 177.), but the ridges are less distinct and the striæ are not strictly granulated.

Villmar; common.

2. *Pleurotomaria Orbignyana*, nob., Tab. nost., XXXII. f. 18, 18 *a*. Var. *a*, f. 19, 19 *a*. Var. *b*, f. 20, 20 *a*.

Shell conoidal, pointed at its summit and enlarged at its base, with six rounded volutions, ornamented with six equally spaced transverse threads obliquely traversed by lamellar folds inclined backward and forming an elegant chequer work on the surface of the shell. Upon the last volution these striæ terminate at a narrow channel which limits its base, and in which are seen striæ, the concavity of which is turned forward. Beyond this, very delicate, concentric threads, sometimes unequal, like those of the upper part of the volutions, are traversed by lines of growth again directed backward and converging toward the umbilicus. Suture canaliculated, in consequence of the junction of the volutions below the channel. Aperture subquadrangular. Columella a little elongated and arcuated. Right lip with a narrow fissure which corresponds to the external channel. Height, 10 millim.; diam. of the base, 9.

Var. *a*. (fig. 19, 19 *a*.) Transverse threads less salient; oblique folds less close-set and rounded.

Var. *b*. (fig. 20, 20 *a*.) Transverse threads very distinct; oblique lamellæ also very prominent; and all the volutions angular.

This shell has some analogy with the *Euomphalus granulatus*, Münst., Beiträge, iii. Heft, Pl. XV. f. 10.

The figure of *Pleur. cancellata*, Phill. Palæoz. Foss. XXXVII. f. 176, is too imperfect to enable us to decide if this species does not belong to one of our varieties.

Villmar; very common.

3. *Pleurotomaria Lonsdalii*, nob., Tab. nost., XXXII. f. 21, 21 *a*.

Shell in form of an abbreviated cone, composed of five volutions, ornamented with transverse granular threads, four in number, and between which are intercalated more delicate striæ. Upon the base

of the last volution, which is nearly sharp-edged, a narrow, scarcely distinct channel, limited beneath by two threads, is recognized by its concave striæ. There are also other granular striæ upon the almost concave base of the shell. Umbilicus rather large. Aperture transverse, small, very depressed. Right lip notched at its outer angle. Height, 5 millim.; diameter of the base, 12.

Villmar; rare.

4. *Pleurotomaria Defrancii*, nob., Tab. nost., XXXII. f. 22, 22 *a*.

Shell conoidal, pointed at the summit, with seven angular volutions, ornamented with two, irregularly plicated transverse keels, the upper one simple and the lower double. Suture deep and canaliculated. The striæ of growth setting off from the suture turn abruptly backward to the second keel composed of two contiguous lamellæ, and beyond which these striæ turn forward and then run toward the base of the aperture. A third keel is seen at the base of the last volution upon the prolongation of the suture, and a fine ridge placed below accompanies it to the right lip. Aperture quadrangular. Columella salient, prolonged and slightly arcuated. Right lip furnished with a linear fissure corresponding to the interval of the two lamellæ of the second keel. Height, 14 millim.; diameter of the base, 10.

In some individuals the upper part of the volutions is decussated like the *Pleurotomaria Orbignyana*. In others the keels are less elevated, and not so sharp, and the two folds of the second are more distant, showing a shallow channel, as in the preceding species.

Villmar; rare; and Visé (Belgium), mountain limestone.

5. *Pleurotomaria undulata*, Phill. Geol. of Yorksh., Part 2. Pl. XV. f. 14.

The spire of some individuals is only a little more elevated than in the shell of the mountain limestone of Bolland.

Slates of Wissenbach; common.

6. *Pleurotomaria* ——— ?

We have found at Paffrath, but very rarely, a small globular species with rounded volutions and which has a rather broad raised band on the upper part of the volutions. It differs from the preceding in this band, which is placed higher up; and in the extremely delicate transverse striæ which accompany it to the base of the last volution.

7. *Pleurotomaria elegans*, nob., Tab. nost., XXXIII. f. 3, 3 *a*, 3 *b*, 3 *c*.

Shell sinistral, turbinated, composed of six regularly convex volutions. Suture simple, rather deep. Volutions covered with very fine and close-set granular striæ, eighteen to twenty in number, upon the last volution. These granulations, which give to the surface of the shell the appearance of shark's skin, are caused by the crossing of the transverse striæ by oblique striæ which run from the suture to the base of each volution. Upon the last this base is bounded by a depressed, scarcely evident band, of which the striæ of growth are directed from front to back. The base of the shell is grooved with concentric striæ traversed by radiating and undulating lines of growth, but without producing the elegant granulations that are seen on the volutions. Aperture depressed, elliptical. Columella salient, a little arched. Slit rather wide, but not deep, placed at the lower angle of the right lip and corresponding to the external band. Height, 13 millim.; diameter of the base, the same.

In this species, remarkable for its sinistral volutions, there are individuals in which the rows of granulations are of two sorts, some composed of united and contiguous grains alternating with others whose grains are distinct and isolated, and of a rhomboidal form; as is seen in the magnified fragment at fig. 3 *c*.

Villmar; common.

8. *Pleurotomaria Beaumonti*, nob., Tab. nost., XXXIII. f. 1, 1 *a*.

Shell conical, composed of five volutions, of which the first are convex and the latter flattened. Volutions ornamented with four or five equally separated, transverse striæ, very finely granular toward the summit of the spire. Upon the last volutions the granulations are changed into oblique, undulated lamellar folds taking the direction of the lines of growth. Sutures canaliculated. The angle which limits the base of the last volution is occupied by two small keels, between which is seen the channel representing the fissure of the right lip, and marked with concave striæ. The base of the shell has eight or nine radiating and undulating lines of growth. Aperture quadrangular, subrhomboidal, with the lips disunited at the upper part. Left lip partly formed by the prolongation of the columella, which is thick and slightly arcuated. Right lip angular and furnished at its internal angle with a rather deep fissure corresponding to the external channel. Height, 10 millim.; diameter of the base, 11.

This shell, upon which there still remain some traces of colour, consisting of brownish longitudinal patches, is somewhat related to *Pl. squamula* (Phill. Geol. Yorks., Part 2, Pl. XV. f. 17), and to the *Trochus Petraeos* (Münst. Beiträge, &c. iii. Heft, Pl. XV. f. 16); but the figures given by these authors are too incomplete to establish a more precise approximation.

Villmar; rare.

9. *Pleurotomaria limbata*, Phill. Geol. of Yorkshire, Part 2, Pl. XV. f. 18. Var. Tab. nost., XXXIII. f. 2.

This shell, remarkable for its form, differs from that which Phillips has figured only in the fine, transverse and undulated striæ which occupy the middle and lower part of the volutions, thus interrupting the oblique folds, which are continuous in the variety from the mountain limestone. The slit of the right lip would correspond to the line of union of the two superposed laminæ which form the sharp and undulated edge of the last volution. Traces of colouring may be observed upon the surface of this shell also.

Paffrath; very rare.

10. *Pleurotomaria exaltata*, nob., Tab. nost., XXXIII. f. 5.

Shell conoidal, formed of eight angular volutions. A rounded and wide band or keel, neatly defined by two striæ, divides the volutions into two unequal parts, of which the upper is the larger and concave, and the lower is convex. Upon the middle of the first the lines of growth which set off from the suture turn abruptly backward until they reach the keel; upon the second, these striæ, setting off from this same keel, first turn forward and then backward to take a radiating direction toward the base of the shell. The arched striæ of the keel are concave on the side of the aperture. Suture deep and undulated by the folds which the striæ of growth form. Base of the last volution limited by a rounded varix. Lower surface of the shell flattened and covered with striæ which converge toward a probably very small umbilicus. Aperture transverse, subpentagonal. Left lip unknown. Inferior edge almost horizontal and slightly arcuated. Right lip angular and furnished with a wide and deep fissure which corresponds to the external band or keel. Height, 70 millim.; diameter of the base, 75.

This fine species, whose form approaches that of a Chinese pagoda, was found at Refrath by Dr. Hasbach.

11. *Pleurotomaria delphinuloides*, *Helicites delphinuloides*, Schlot., Petref., Pl. XI. f. 4. Tab. nost., XXXIII. f. 4. var. f. 4 *a*.

We have given a new representation of this species which is very imperfectly figured in Schlotheim's work. The shell is not even in perspective, and the drawing does not show the disposition of the striæ

of growth. Broad, slightly prominent; radiating and undulating folds may also be seen upon the base of the last volution. Some individuals, moreover, show obsolete striæ upon this part of the shell.

We have also given a figure of one of the numerous varieties of this species (Pl. XXXIII. f. 4 *a.*). It is remarkable for the great elevation of the spire. The volutions are less flattened on the upper part than in the other varieties. The lines of growth are thicker and the band is placed lower. Perhaps these characters may at some future time cause this shell to be regarded as a distinct species.

Although very plentiful in the limestones of Paffrath, the *Pl. delphinuloides* is rare in all other localities. The cast figured at Pl. LVII. f. 17. of Messrs. Sedgwick and Murchison's memoir on Devonshire (Geol. Trans., vol. v.) seems to be a small individual of our turriculated variety. The *Pl. vittata* (Phill. Geol. Yorks., Part 2, Pl. XV. f. 24) might also perhaps be regarded as a variety between the two that we have figured, as well as the *Helix cirriformis*, Sowerby (Min. Con., Pl. CLXXI. f. 2. *Pleurotomaria*, Index).

Paffrath; very common; the limestones of Devonshire and mountain limestone of England.

EUOMPHALUS.—I. Species with rounded or very slightly carinated volutions.

1. *Euomphalus Goldfussii*, nob. *Euomphalus spinosus*, Goldf. Bonn Mus., Tab. nost., XXXIV. f. 1, 1 *a*, 2, 2 *a*.

Shell discoid, flattened above, deeply excavated beneath. Six rounded volutions, very slightly convex and nearly smooth above. In the middle numerous, oblique, rather irregular striæ in the first place run forward and then backward to reach the inner suture. In passing over the lower plane of the volutions these striæ are interrupted or modified by irregular folds. These latter produce unequal tubercles, inclined forward, sometimes spinose, sometimes pliciform, and 10 or 12 in number upon the base of each volution and placed at equal distances from the inner suture and the outer edge. In the umbilicus the last volution but one is also armed with spiniform tubercles placed against the suture. The transverse striæ are usually distinct and very regular upon the first volutions, at the bottom of the umbilicus, and near its top they often unite in bundles and join the tubercles. The latter become gradually slighter and disappear altogether upon the first volutions. Upon the middle part of the volutions may also be observed zigzag striæ which cross the preceding and cause a reticulated or finely granular character, which is still more distinct in young individuals without tubercles. Umbilicus very open, showing all the volutions. Aperture round, scarcely modified by the penult volution and occupying two-fifths of the total diameter.

In young individuals (fig. 2, 2 *a.*) the decussated striæ are more distinct both above and beneath each volution than in the adult, in which they often disappear even from above as the tubercles are developed beneath. In the young shell the involution is almost symmetrical and on the same plane, but with age the increase in the height is made almost exclusively downwards, of which the result is a very large umbilicus without great elevation of spire.

This fine species is distinguished from *E. nodosus* (Sow. Min. Con., Tab. XLVI.), by the absence of the keel from the upper part of the volutions, by the form of its spinous folds, and by the striæ with which its surface is ornamented. It is equally distinguished from the *E. bifrons*, Phillips (Geol. Yorks., Part 2, Pl. III. f. 4.), by the position of its tubercles, which are placed on the lower instead of the upper side of the volutions.

Lustheide, Paffrath; rare.

2. *Euomphalus Labadyei.* Tab. nost., XXXIII. f. 6, 6 *a*, 6 *b*.

Shell discoid, composed of five volutions slightly carinated above and regularly plicated beneath.

Folds twenty-four in number, surrounding a very open umbilicus in which are seen all the volutions. Aperture subpentagonal, its width equal to a third of the total diameter.

This small species is distinguished from the *E. nodosus*, Sow., by its stature, which is always much less, and by its folds instead of tubercles. The number of these folds is double that of the tubercles, and further, they radiate toward the umbilicus, while in Sowerby's species they are elongated even in the direction of the involution. This shell might then be regarded as a true Solarium, since it possesses the only character which distinguishes this latter genus from *Euomphalus*.

Paffrath; rare. Newton. Tournay, mountain limestone.

3. *Euomphalus lævis*, nob. *Helicites priscus*, Schlot. Petref., Pl. X. f. 1. Tab. nost., XXXIII. f. 8, 8 *a*.

Shell subdiscoid. Spire somewhat elevated, composed of five volutions, subcarinated above and rounded beneath. Suture simple, rather deep. Striæ of growth very fine, close-set and slightly undulated. Umbilicus rather wide, showing the interior of the spire. Aperture quadrilateral, rounded. Shell thick.

This shell, which seems to be related to *Helicites priscus*, bears the greatest analogy to certain *Euomphali* of the mountain limestone.

Paffrath; rare.

4. *Euomphalus planorbis*, nob., Tab. nost., XXXIII. f. 7, 7 *a*.

Shell discoid, planorbular, composed of seven rounded volutions, increasing slowly, contiguous, but not embracing in young individuals, which are almost symmetrical. Suture simple and deep. Spire scarcely raised above the last volution. Striæ of growth numerous, radiating, simple and straight. Umbilicus very open. Aperture rounded, nearly entire.

This species approaches very near to the *E. serpens* of Phillips's Palæoz. Foss., XXXVI. f. 172.

Villmar, Paffrath; common.

5. *Euomphalus Serpula*, de Koninck, Descrip. Anim. Foss. Belgique, Tab. nost., XXXIII. f. 9, 9 *a*, 9 *b*.

This shell differs from the last, of which it is perhaps only a variety, in its volutions being often separated and free. Sometimes united and contiguous when young, they separate and become distant with age. Sometimes the involution is continued on the same plane, but occasionally it forms an irregular, more or less elevated spire.

This *Euomphalus*, common enough at Paffrath, is not less so in the mountain limestone of Belgium and Ireland.

6. *Euomphalus annulatus*, Phill. Pal. Fos., Pl. LX. fig. 172 *. Tab. nost., XXXIII. f. 11, 11 *a*.

Shell discoid, planorbular, nearly flat above, excavated beneath, composed of six rounded, exposed volutions, increasing slowly, and contiguous but not embracing. Regular, numerous, transverse striæ, set off from both sides of the suture, and rise to one-third of the surface of the volutions, then subdivide into four or five much finer striæ in passing over the back of the shell. Aperture entire, rounded, furnished with a salient varix. A second varix may be seen, also upon the last volution, at some distance from the aperture.

This little shell is remarkable for its varices, in which it resembles certain Serpulæ.

Paffrath; rare. Newton.

II. Species with more or less sharp-edged angular volutions.

7. *Euomphalus qualteriatus*, Bronn. Leth. Geog., Pl. II. f. 1, *a*, *b*. *Helicites qualteriatus*, Schlot., Pl. XI. f. 3. Var. nob.

We regard as a simple variety of this species a shell which only differs in its less salient spire, in its less sharp external edge, and in its aperture, which the more rapid increase of the last volution renders higher.

Refrath; rare.

8. *Euomphalus trigonalis*, Goldf. Bonn Mus. *Solarium Petropolitanum*, Pander, I. f. 3, XXVIII. f. 14, p. 150. Tab. nost., XXXIII. f. 10, 10 *a*.

Shell flat or slightly concave above, subconoidal beneath, composed of five volutions, the first of which are rounded and convex, and form a very low spire, and the last, which is very large, constitutes nearly the whole of the shell. It is divided by a rounded keel which reaches the level of the spire and limits the upper and concave part of this last volution; the other part, which forms a right angle with the latter, is prolonged and rounded beneath toward the base. Suture deep and channelled. Aperture forming an elongated curvilinear triangle.

Although we have only incomplete casts of this shell, which bears a certain analogy with *Helicina expansa* (Min. Con., Pl. CCLXXIII. f. 1–3. *Rotella Index*), we have mentioned and figured it on account of its singular form. Some casts have a brilliant blackish covering.

Paffrath.

9. *Euomphalus Schnurii*, nob., Tab. nost., XXXIV. f. 7, 7 *a*, 7 *b*.

Shell discoidal, planorbular, almost flat above, very widely excavated beneath, and composed of five contiguous, but not embracing, volutions. Volutions ornamented with two very salient keels, one at the upper part, and the other limiting the base of each volution. Very fine, close-set striæ radiate from both sides of the suture, passing over the keels and producing there a row of rather indistinct but regular granulations. Upon the back of the shell these striæ are still finer and inclined backwards. Upon the first volutions may be remarked a third central keel, which corresponds to the suture of the volutions which cover it. Aperture subpentagonal, wider than high, not modified by the penultimate volution.

Although the striæ do not continue regularly from the suture to the base of the volutions, but are inflected a little in passing over the two keels, we do not think there is ever any true fissure in the right lip, or that this shell could be placed in the genus *Schizostoma*. Besides, it has a certain analogy with *Euomphalus Catillus* (Sow. Min. Con., Tab. XLV. f. 3, 4.), which in our opinion is not a true *Schizostoma*. The *E. Schnurii* differs from *E. Catillus* in the form of its volutions, which may be ascertained by comparing the aperture of the two species. The aperture of *E. Catillus* is triangular and higher than it is wide, which is precisely the reverse in *E. Schnurii*, in which moreover it is pentagonal.

Eifel; rare.

1. *Schizostoma radiata*, nob. *Euomphalus radiatus*, Goldf. Bonn Mus., id. Phil. Pal. Fos., Pl. LX. f. 171*. Tab. nost., XXXIV. f. 3, 3 *a*, 3 *b*.

Shell sinistral, planorbular, concave on both sides, of five volutions (not embracing), slightly convex above, but much more developed beneath. There are two keels, the superior of which is very distinct and forms a sort of circular, thin and sharp-edged crest upon the last volution; the inferior is rounded and placed on the edge of a very open umbilicus. Suture deep. Above, the volutions are ornamented with numerous regular folds, arcuated forward, and prolonged by fine diverging striæ upon the anterior crest. Beneath, other striæ, setting off from the edge of the same crest, recurve in an inverse direction, at first forward and then backward, to join the inner suture. Aperture imperfectly triangular, with sinuous edges, and presenting on the external edges two pinchings (*pincements*) which correspond to the keels.

This shell, remarkable for its sinistral involution, is not less so for the lamellar crest with which it is

surrounded. The inverse arrangement of the striæ above and beneath shows that it must have been formed by the simultaneous secretion from the two contiguous edges of a fissure in the mantle of the animal, a circumstance analogous to that which occurs in var. *a.* of *Murchisonia angulata* and in *Pleurotomaria Defrancii**. We have therefore placed this shell in the genus *Schizostoma*, to which also *E. elatus*, of Hisinger (Pl. XI. f. 7), ought to be referred. This latter has a similarly striated keel.

Eifel; Newton.

2. *Schizostoma Puzosii*, nob., Tab. nost., XXXIV. f. 8, 8 *a*, 8 *b*.

Shell discoidal, planorbular, formed of six volutions flattened above and convex beneath. Suture wide and channelled. Volutions ornamented at their middle part with eight or ten transverse, undulated and unequally separated striæ, which are crossed upon the first volutions by longitudinal lines. These latter, at first simple and straight at setting off from the canal of the suture, soon become divided into two or three as they approach the lower edge. The latter is formed of two equal keels which separate a shallow decurrent channel. Setting off from the upper keel the striæ go forward again to reach the suture; at length upon the last volution they turn backward and run toward the umbilicus after having made still one or two more wide undulations. On the base of the shell there are two bands of concentric striæ separated by a zone which is destitute of striæ, as well as the part surrounding the umbilicus where there are only striæ of growth and obsolete folds. Umbilicus funnel-shaped, showing a part of the spire within. Aperture transverse, with a sinuous edge, and disunited above, rounded beneath and straight above. External angle of the lip straight, furnished with a shallow notch corresponding to the upper keel. Aperture equal to two-fifths of the diameter of the shell.

We are indebted to M. Puzos, to whom we have dedicated it, for the knowledge of this fine shell.

Eifel; very rare.

1. *Cirrus Leonhardi*, nob., Tab. nost., XXXIV. f. 9, 9 *a*.

Shell of a short conical form, pointed at the summit, very wide at the base, and composed of seven angular volutions. Suture wide and deeply channelled. The first volutions have two simple keels, which upon the following are loaded with transversely compressed tubercles, almost contiguous, and increasing in size. Upon the last volution a third keel, also nodulose, forms a continuation to the suture. Lastly, the umbilicus is surrounded by a varix which divides the base of the shell into two parts. Upon the last volution lines of growth, very distinct, irregular, and much undulated, pass over the folds of each keel and take an oblique direction toward the umbilicus. This latter is deep and funnel-shaped, and shows a part of the spire within. Aperture entire, subpentagonal, its edges joined and undulated, nearly equal to half the total diameter of the shell.

Paffrath; rare.

2. *Cirrus rotundatus*, Sow. Pl. CCCCXXIX. f. 1, 2.

A smaller and more conoidal variety.

Paffrath.

Rotella heliciformis, Goldf. Bonn Mus. *Helicites helicinæformis*, Schlot., Petref., Pl. XI. f. 6.

Paffrath; common.

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* For an explanation of the mode of closing the fissure in these various genera see Bull. de la Soc. Géol. de France, vol. xii. p. 157, *note*.

1. *Natica margaritifera*, nob., Tab. nost., XXXIV. f. 4, 4 *a*.

Shell ovoid, with a very short spire composed of four volutions, the last alone forming nearly the whole of the shell. Upper volutions ornamented with two or three rows of granulations between which new rows become interposed as the shell increases, so as to present as many as twelve upon the last volution. Six or seven, larger than the others, may then be reckoned, between which the smaller are placed; or they may be all of the same size and equally distant. Suture subcanaliculated. Aperture semilunar, oblique to the axis, rounded at the base and contracted at the summit. Left lip entirely covered by a callosity which hides the umbilicus and reaches to the upper angle. Right lip simple. Height, 10 millim.; diameter, 8.

Paffrath; rare.

2. *Natica subcostata*, nob. *Nerita subcostata*, Goldf. Bonn Mus. Tab. nost., XXXIV. f. 5, 5 *a*, var. *a*, f. 6.

Shell subglobular, spire short, composed of five or six volutions, flattened toward the middle part, the last very large, composing nearly the whole of the shell. Suture rather deep. Spire covered with greater or smaller, close-set and oblique folds, which commence at the suture and bifurcate on reaching the middle part of each volution: upon the last they are prolonged as far as to the callosity of the left lip. In some individuals these folds become decided ribs which do not bifurcate, and between other supplementary ribs which accompany them to the base. There are three transverse rows of brown spots which are the remains of the colouring matter of the shell. Aperture large, semilunar, oblique to the axis, rounded at the extremities. Left lip flattened, completely covered, together with the columella, by a callosity which unites with the right lip at the upper angle. Base of the aperture rounded and slightly effuse. Right lip dilated.

Var. *a*. fig. 6. (*Nat. nexicosta*, Phill. Pal. Fos., Pl. XXXVI. f. 174.) Shell much more globular than the preceding. Volutions regularly rounded. Aperture more dilated. Callosity of the left lip narrower.

We do not think that the *Murex harpula*, Sow. (Min. Conch., Pl. DLXXVIII. f. 5), belongs to this species, as Bronn seems disposed to admit. Mr. Phillips unites both under the name of *Macrocheilus harpula* (*loc. cit.* XXXIX. f. 197, p. 105), but his figure does not appear sufficiently complete to enable us to pronounce with certainty on the resemblance.

Paffrath; common. Devonshire.

Pileopsis cassideus, nob., Tab. nost., XXXIV. f. 10, 10 *a*.

Shell of a very short conical form, very oblique. Summit pointed, recurved, and extending beyond the base. Aperture subelliptical, transverse. From the summit sets off a salient keel which descends to the base, where it produces an indistinct ridge (*pincement peu prononcé*).

Grauwacke of Kemmenau; very rare.

Orbicula ——— ?

Numerous Orbiculæ are found in the Kemmenau beds, but not sufficiently well-preserved to be described. They attain dimensions much greater than any of the species yet known belonging to the older beds.

Kemmenau, Le Faou, Brittany.

Lingula ——— ?

A species related to *L. cornea*, Sow. (Sil. Syst., Pl. III. f. 3).

Lethmate; rare.

1. *Terebratula concentrica*, de Buch, Mém. de la Soc. Géol. de France, t. iii. p. 214. Bull. *id.* xi. Pl. II. f. 1.

The position of the spires in this species was not known, but we have ascertained that they are placed as in the *Spiriferæ*, that is to say, their opposite extremities are directed toward the lateral angles. In the *Terebratulæ*, as Von Buch observes, the ciliated arms are usually turned one toward the other, or placed vertically in the shell and ending nearly in the middle of the ventral valve (*T. prisca*).

Therefore this character of the position of the ciliated arms is not found exclusively in the *Spiriferæ*, and we are already acquainted with three species of *Terebratula* in which it exists, *T. concentrica*, *T. Roissyi* (Bull. de la Soc. Géol. de France, vol. xi. Pl. III.), and *T. ferita*, de Buch (Pl. XXXV. f. 3 *b*, of this memoir). Besides which, the *Spirifer bisulcatus*, Sow., figured at the end of Prestwich's memoir (Trans. of Geol. Soc. of Lond., vol. v. Pl. XXXIX. f. 21.), has, on the contrary, its spires placed vertically as in certain *Terebratulæ*. The *T. concentrica* found at Néhou (La Manche) has a more distinct fold to the ventral valve. It is also wider, which brings it nearer to the form of certain *Spiriferæ*.

Refrath, Eifel. Tchudova, Chimay, Huy, Couvin, Boulogne, Néhou. Newton, Torquay, Devonshire.

2. *Terebratula Voltzii*, nob., Tab. nost., XXXV. f. 4, 4 *a*, 4 *b*.

Shell rounded, inflated, valves equally gibbose, covered with very fine, regular, radiating striæ from sixty-five to seventy in number. These striæ, before reaching the edge of the valves, combine in bundles, by twos and threes, so as to form four or five obsolete folds in front. Beak of the dorsal valve small, inflated and slightly recurved. Area triangular. Deltidium indistinct. Perforation round, placed immediately under the point of the beak. Dorsal sinus very much raised. Ventral valve more or less gibbose according to age. Varix slightly evident. Cardinal edges nearly rectangular. Lateral angles slightly curved. Width, 11½ millim.; length, 13; thickness, 10.

This species is distinguished from all those with which it might be confounded, by the extreme delicacy of its striæ. These latter, by combining together in the form of folds toward the edges of the valves, bear some analogy to what is seen in *T. furcillata* and *T. Schnurii*. Young individuals are much less ventricose, and they are subtrigonal. Theodori, see de Buch, Mém. Géol. Soc. France, Pl. XIV. f. 13, Pl. XX. f. 12, p. 143.

Paffrath; rare.

3. *Terebratula Gryphus*, de Buch, Mém. de la Soc. Géol. de France, iii. Pl. XVI. f. 18. *Uncites Gryphus*, Defr. Dict. Sc. Nat., tome LVI. p. 257. *Terebratulithes Gryphus*, Schlot., Petref. p. 259., Pl. XIX. f. 1. *Gypidia Gryphoides*, Goldf. bei Dechen Handb. der Geogn. von De la Beche, s. 527.

This shell is very common in the limestone beds of Paffrath and Hagen in Westphalia, where it is associated with *Strygocephali* and *Megalodontes*. Casts of the inside are also found in the grauwacke of Salchendorf, near Siegen.

4. *Terebratula caïqua*, nob., Tab. nost., XXXV. f. 1, 1 *a*, 1 *b*.

Shell very elongated, elliptical. Valves equally ventricose, smooth, or only presenting striæ of growth which are not numerous. Beak of the dorsal valve inflated, very much recurved, and touching the other valve. Aperture round and terminal. Area very small. Deltidium none. The dorsal valve is inflated toward the middle, where it presents a sort of obsolete keel which soon disappears. Ventral valve slightly keeled, attaining its greatest height at the middle, and forming a very regular curve from the beak to the front. The latter is rounded, without any trace of fold or sinus. The angle of the cardinal edges is 90°. These latter run into the lateral edges, which unite together in front by a regular and continuous curve. Length, 59 millim.; width, 38; thickness, 37.

This shell, shaped like a little canoe or *caïque*, pretty nearly resembles the *Terebratula lagenalis*, Schlotheim, which belongs to the middle oolitic beds. It differs, nevertheless, in the angle of the cardinal edges, which is much greater, in the absence of the truncation in front, and in that of the three

planes (*plans*), which terminate there. Although we are only yet acquainted with a single individual of this species, it appeared to us to be too evidently distinct from all its congeners to leave it undescribed*.

Paffrath; very rare.

5. *Terebratula ferita*, de Buch, Mém. de la Soc. Géol. de France, t. iii. Pl. XVII. f. 4, p. 182. Tab. nost., XXXV. f. 3 *b*, var. f. 3, 3 *a*.

Our variety is so completely distinguished at first sight from the type of *T. ferita*, that it might be regarded as a species if it did not vary much in itself, and if there did not exist sufficiently numerous intermediate varieties to establish a specific identity. This variety (fig. 3.) is less rounded than that described by Von Buch. The elongated beak is straight and the aperture altogether terminal. The area is much elevated, and divided in two by a linear deltidium. On each valve there are seven unequal folds, which are very distinct, rounded, and not always symmetrical. In one of the individuals represented at fig. 3, the middle of the front does not exactly correspond to any one fold or groove, while in the other (fig. 3 *a*.) is to be seen a small central fold corresponding to a groove in the ventral valve. Transverse striæ, concentrical, regular and pretty distinct, particularly toward the edge of the valves. The surface of these latter, as well as of the area and of the deltidium, are very finely and elegantly punctulated.

We have also represented (fig. 3.) an individual belonging to the type of the species, of which, the ventral valve being partially destroyed, the spires turned outwards are seen; a character which had long been regarded as peculiar to the *Spiriferæ*.

Eifel, Villmar, Plymouth, Newton, Barton.

6. *Terebratula lepida*, Goldf. Bonn Mus., Tab. nost., XXXV. f. 2, 2 *a*, 2 *b*, 2 *c*.

Shell very small, oval, sometimes globular. Ventral valve elliptical. Median sinus wide, shallow, limited by two rounded folds on each side. A straight filiform fold at the bottom of the sinus. Concentric striæ regular, and a little squamose. Dorsal valve ventricose, subcarinated, furnished with three rounded folds on each side of the dorsal sinus, which is shallow. Striæ similar to those of the other valve. Beak extremely small. Aperture placed beneath, and touching the ventral valve. Length, 6 millim.; width, 5; thickness, 4.

Its form would bring this species into *Atrypa* of Dalman, if that genus could be preserved in a scientific classification, which we think it cannot.

Eifel; rare.

Strygocephalus.

Although this genus belongs evidently to the order of *Brachiopoda*, the shells of which it is composed present characters, both internally and externally, which distinguish it equally from the *Terebratulæ* and the *Spiriferi*. De Buch is disposed to refer the *Strygocephali* to the first of these genera, in which they would compose a small group with the *Terebratula Gryphus*. We have, nevertheless, preserved to them the name by which they are generally known.

1. *Strygocephalus Burtini*, Defr. Dict. des Sciences Nat., tome li. p. 102. Pl. LXXV. f. 1, 1 *a*—*c*. Bronn, Leth. Geog., Pl. II. f. 5. *Terebrat. porrecta*, Sow. Min. Con., Pl. DLXXVI. f. 1. *Terebr. Strygocephalus*, de Buch. Mém. Géol. Soc. de France, t. iii. p. 230.

Like most of the *Brachiopoda*, the *Strygocephali* present variations the limits of which it is difficult to ascertain. Sometimes the form of the area and the curve of the beak vary so much as to have caused the establishment of distinct species. Thus the *S. rostratus* is really nothing more than a variation of the *S. Burtini*, in which the very recurved beak hides a part of the area and almost touches the ventral

* Since this description was in type M. Goldfuss has seen our plates, and he has informed us that *Terebratula caïqua* is the *T. amygdalina* of the Bonn Museum. Aug. 1842.

valve. The *S. Burtini* is very abundant at Paffrath, at Villmar, and in the Eifel. It is found also at Dietz, Brilon upon the Lahn, at Chimay, and in Devonshire.

2. *Strygocephalus dorsalis*, Goldf. Bonn Mus. Tab. nost., XXXV. f. 5, 5 *a*.

This species, named by Goldfuss, differs from the preceding only in having a more or less distinct median groove upon each valve. This groove is prolonged to the beak of the dorsal valve, and on the contrary only reaches the middle of the ventral valve. Very delicate, slightly undulated, longitudinal striæ, which cover the whole shell and descend from the beaks to the edge of the valves, do not exist in the *S. Burtini*; and the cardinal line, instead of being regularly arched, is formed of two straight lines, which unite under the beak and present a very obtuse angle.

Paffrath; common; Devonshire.

Pentamerus Knightii, Sow. Min. Conch., Pl. XXVIII. Murch. Sil. Syst., Pl. VI. f. 8, &c.

Contrary to the opinion of de Buch, who unites the *Pentamerus* to the *Terebratula Gryphus*, (Mém. Géol. Soc. de France, t. iii. p. 174) we think they ought still to be distinguished. The *P. Knightii* never has the elongated form of the *T. Gryphus*, nor the pointed beaks where the cardinal edges meet at an angle of 40°. We refer to *P. Knightii* some siliceous casts from the grauwacke of Greifensten in Westphalia, and from Hohenzolen.

1. *Spirifer curvatus*, *Terebratulithes curvatus*, Schlot. Petrefact., Pl. XIX. f. 2.

According to Mr. Hasbach this species is found at Paffrath. It exists also in the Eifel.

2. *Spirifer aperturatus*, *Terebratulithes aperturatus*, Schlot. Petref., Pl. XVII. f. 1. *Trigonotretra aperturata*, Bronn, Leth. Geog., Pl. II. f. 13. *Delthyris canalifera*, Goldf. Bonn Mus. *D. aperturata*, de Buch, Mém. de la Soc. Géol. de France, t. iv. pl. XIII. f. 19. Varieties, Tab. nost., XXXV. var. *a*. f. 7, 7 *a*, and var. *b*. f. 8, 8 *a*.

Bronn unites this species to the *Terebratula canalifera*, Lam., to make his *Trigonotreta aperturata*. The height and the form of the area are variable, and the beak of the dorsal valve is more or less recurved. We shall particularize the two following varieties.

Var. *a*. *cuspidata*, f. 7, 7 *a*. Area flat, perpendicular to the hinge, and forming a rectangular triangle whose hypothenuse is the hinge itself. The general form of the shell is like that of *S. cuspidatus* (Sow. Min. Conch., Tab. CXX.), from which, however, it is distinguished by having numerous folds in the sinus and on the varix (which are wanting in the species of the mountain limestone), and in the greater number of its lateral folds. Between this variety, which appears to remain of a small size, and the type of the species, there exists an uninterrupted series of intermediate forms, in which the area has a tendency to become concave, and the valves to assume larger and larger proportions relatively to this part. The number of folds, however, remains the same.

Refrath, and at Paffrath; as casts.

Var. *b*. *echinulata*, f. 8, 8 *a*. The form of this is the same as that of the common variety; the area is very elevated, its height being two-fifths of the length of the hinge. This shell is well characterized by the small spines with which the folds are covered, the grooves which separate them remaining smooth. These spines are short, truncated, close-set, and all directed downwards, thus giving to the folds some resemblance to certain spines of *Cidarites*. There are thirty folds on each side of the varix and of the sinus, and twenty upon each of these last-mentioned parts. They are, therefore, finer and nearly double the number of those of the other varieties. The sinus is also less deep and the varix less salient, and its folds bifurcate more frequently than on the sides.

Bensberg.

De Buch unites the *Terebratula subconica* (Conch. Anomites subconicus, Mart., Petrif. Derb. Tab. XLVII. f. 5–7.) and *S. bisulcatus* (Sow. Min. Conch. Tab. CCCCXCIV. f. 1, 2.) to the *S. aperturatus*,

but we think there is reason to preserve these species, particularly the last, which differs notably in the beak and the area.

3. *Spirifer mediotextus*, nob., Tab. nost., XXXV. f. 9, 9 *a*, 9 *b*, 9 *c*.

Shell depressed, semilunar, ventral valve covered with radiating ribs, which are simple, slightly undulated, twenty-four to twenty-six in number on each side, and which become narrower and more close-set as they approach nearer to the extremities of the hinge. Beak slightly recurved upon the area. In place of a varix there is a slight depression covered by a very delicate net-work, forming longitudinal and transverse capillary striæ. This net-work is not prolonged to the beak, although the groove reaches the latter part. Dorsal valve more ventricose than the ventral, and having the same number of folds similarly placed. Area large, very slightly concave. Upper angle 125°. Beaks scarcely recurved. Aperture triangular, wide. Sinus large, flat, and covered with a net-work similar to that of the other valve. Front presenting a double depression, and the junction of the valves at this part forming a simple, straight and horizontal line. This latter character is not yet known in any other species of the genus. Length of the hinge, 40 millim.; of the shell, 24; thickness, 16.

Refrath; very rare.

4. *Spirifer cheiropteryx*, nob., Tab. nost., XXXV. f. 6, 6 *a*, 6 *b*.

Shell winged, very short, valves equally ventricose. Ventral valve divided into three parts by two elevated ribs, which set off from the beak and confine between them a rather indistinct varix. Two or three obsolete folds on each side. Beak slightly prominent, and touching the hinge. Lateral edges very concave, prolonged into wings. Dorsal valve divided by two ribs, similar to those of the other valve. Area very long, narrow, concave. Aperture triangular, extending from the beak to the hinge. Beak slightly recurved. Median sinus wide and deep, marked with pliciform striæ of growth, like the rest of the surface. Front presenting a broad and deep fold, whose edges, resulting from the junction of the dorsal and ventral ribs, are unequally prolonged in the direction of the ribs. Length of the hinge, 27 millim.; from the beak to the inner angle of the front, 11; thickness, 7.

The two ribs are so developed upon each valve that these latter are divided into three concave lobes. The species is no less remarkable for this character than for the great length of the hinge. In the only two specimens we know, the prolongation of the ribs is unequal, and the shell represents pretty well the extended wing of a Bat. This disposition of the ribs and the pliciform striæ of growth recal to mind what is seen in *T. trigonella*. (Schlot., de Buch, Mém. Géol. Soc. France, t. iii. p. 189. Pl. XVII. f. 2.*)

We have found in the mountain limestone of Visé, a shell which seems to be only a variety of *S. cheiropteryx*. It is less transverse, the area is more elevated, the ribs are less prominent and less prolonged beyond the front, and lastly the folds and the striæ of growth are more distinct than in our specimens from Paffrath.

Paffrath; very rare.

5. *Spirifer heteroclitus*, de Blainv., Malac., Pl. L. f. 3. De Buch, Mém. Géol. Soc. France, iv. Pl. VIII. f. 11. *Calceola heteroclita*, Defr. Dict. des Sc. Nat., Planche Ostracées et Conchacées, f. 3.

We possess only a cast of this species: it comes from Villmar, where it appears to be very rare. *Sp. heteroclita* is found also in the Eifel and in Devonshire.

6. *Spirifer trapezoidalis*, *Cyrtia trapezoidalis*, Dalm., Acad. Holm. 1827, Pl. III. f. 2. Id. Bronn, Leth. *supra*, Pl. III. f. 2. De Buch, *loc. cit.* Geog., Pl. VIII. f. 12.

This species is found at Paffrath, according to de Buch.

7. *Spirifer glaber*, Sow. Min. Conch., Pl. CCLXIX. f. 1, 2. Variety *minor*, nob.

This shell, very abundant in certain beds at Paffrath, seems to be the miniature of the *Sp. glaber*, which

is found in the mountain limestone of Belgium, Ireland, Yorkshire and Derbyshire; wherefore, notwithstanding the great difference of its stature, we can only give it as a variety. When the shell is not decomposed, which happens rarely, extremely fine radiating striæ may be seen, crossed by the lines of growth. The shell, when partly decomposed, is of a more or less silvery dull white.

Paffrath; very common.

8. *Spirifer resupinatus, Terebratulithes vestitus,* Schlot. Petrefact., Pl. XV. f. 1.

The specimens collected at Mettmann near Elbersfield in the Strygocephalus limestone, are identical with those of the mountain limestone: but those of the Eifel differ somewhat, and come nearer to *Terebratulithes striatulus,* Schlot., Pl. XV. f. 4.

Mettmann and mountain limestone of Visé.

9. *Spirifer connivens,* Phill. Geol. of Yorksh., Part ii. Pl. XI. f. 2.

Very small triangular *Spiriferi* are found at Paffrath, similar to *Sp. connivens.* This species is very common in the mountain limestone of Yorkshire, and we have also found it at Boulogne. It appears to us to be only a variety of the preceding species. The specimens from Paffrath are distinguished merely by eight or ten rather more distinct radiating striæ.

The *Spiriferi* of the family of *Impressi* of de Buch, that is to say, the *Sp.* (*Terebratulithes*) *striatulus, Sp.* (*T.*) *similis, Sp.* (*T.*) *excisus, Sp.* (*T.*) *vestitus,* Schlot., *Sp.* (*T.*) *resupinatus,* Mart., and *Sp. connivens* of Phill., are very much like each other, and might be considered as varieties of the same species. Their specific differences, if any exist, appear to us at least very difficult to ascertain. It is natural enough that this species, being ill-defined and subject to numerous varieties, should be found in beds of very different ages.

Leptæna sericea, Sow. Sil. Syst., Pl. XIX. f. 2.

This very finely striated shell is found at Braubach.

1. *Orthis Murchisoni,* nob., Tab. nost., XXXVI. f. 2.

Upper valve forming rather more than a half-circle, flat above, folding back below toward the edges, and ornamented with nineteen radiating ribs, sharp-edged near the beak, and slightly inflected upon the sides. These ribs curve toward the front and follow the form of the valve. They are very finely striated, and the striæ as they bifurcate become more and more numerous on approaching the edges, where fifteen may be reckoned upon each rib. Ribs wide, flattened, and having a tendency to disappear near the lateral edges. Hinge straight. Beak forming a scarcely evident prominence above the cardinal line. Lateral edges uniting to the hinge at an angle of 85°. Ventral valve unknown.

A fossil collected by the late Rev. J. J. Conybeare, on Snowdon in Wales, and figured at Pl. XXV. f. 2, in the Fourth Vol. (1st Series) of the Trans. of the Geol. Soc. of London, appears to be nearly similar to this species.

Siegen, grauwacke; rare.

2. *Orthis Sedgwicki,* nob., Tab. nost., XXXVI. f. 1.

Ventral valve forming rather more than a half-circle. Hinge straight, without area. From the beak, which touches the cardinal line without any prominence, set off twenty folds, which soon bifurcate, to become more and more subdivided as they approach the edges, where they are only represented by bundles of finely striated folds. Dorsal valve unknown.

The *Orthis Sedgwicki* is related to *O. Murchisoni,* and this affinity is naturally expressed by the approximation of two celebrated names, as intimately united by the noble friendship of those who bear them as by the unity of their labours.

Grauwacke of Landerskron and Siegen; rare.

3. *Orthis Lepis*, nob. *Strophomena lepis*, Bronn, Leth. Geog., Pl. II. f. 7. *Productus elegans*, Hüpsch, Natur. Nieder. Deutschl., Pl. I. f. 7, 8. Isis, 1825, 12e Cahier, Pl. XIII. Stein. Mém. de la Soc. Géol. de France, i. p. 361. Tab. nost., XXXVI. f. 4, 4 *a*.

We have to remark upon this species, that the straight hinge is very nearly equal to the width of the shell, and that it is composed of two very distinct and much elongated areæ. Upon the middle of each area there is a triangular fissure, remarkable for its smallness in proportion to the shell. These fissures are usually closed, and are one-third of a millim. in width.

The *O. Lepis* differs from *Leptæna transversalis*, Dalm., *Orthis transversalis*, de Buch, in its still more transverse and less elongated form, and by the dilatation of the lateral edges, which, in the *L. transversalis*, have a tendency to approximate in descending toward the front.

The form of *O. Lepis* being the same as that of the *Producti*, it is not surprising that it should have been placed in that genus, to which Dalman gave the name of *Leptæna*. In some individuals where the area is still more contracted it becomes almost impossible to perceive the fissure. Those species called *Leptæna* by the Danish naturalist, and even by J. Sowerby in Murchison's Silurian System, form the true connecting links with the *Producti*, in which the area and the triangular fissure are no longer discernible.

4. *Orthis subarachnoidea*, nob. (*O. arachnoidea*, Phill. Pal. Fos., Pl. XXVII. f. 114, *non* Spirifer; id. Geol. Yorks., Part 2, Pl. XI. f. 4.), Tab. nost., XXXVI. f. 3.

Shell depressed; dorsal valve presenting the form of an ellipsis truncated by the cardinal line, which is straight, and as wide as the shell. The lateral edges, at right angles to the hinge, are rounded, and coalesce with the front so as to describe three-fourths of a regular ellipsis. Fine and deep striæ (perhaps granular at their extremities) set off from the beak and radiate toward the edges, being subdivided several times. Ventral valve unknown. Length, 60 millim.; width, 48.

This species has some analogy with the *Sp. arachnoidea*, Phill. (Geol. of Yorksh., Part 2, Pl. XI. f. 4.), but as this author only gives the upper valve, which we have not, we have not yet thought proper to consider as identical shells so incompletely known, and which, furthermore, belong to very different geological systems.

Grauwacke of Kemmenau and Ems. It is found also in Devonshire.

5. *Orthis minuta*, Goldf. De Buch, Mém. de la Soc. Géol. de France, t. iv. p. 217, Tab. nost., XXXVI. f. 5, 5 *a*, 5 *b*.

Shell nearly hemispherical, presenting on each valve twenty-one very distinct radiating ribs, which are simple, or rarely bifurcate. Hinge straight. Ventral valve semicircular, concave, particularly under the beak. Lateral edges forming an angle of 110° with the hinge. Median apophysis, salient upon the area above the beak. Dorsal valve ventricose, beak very much recurved and somewhat ventricose. Area very narrow, concave. Aperture very small, closed, and partly covered by the apophysis of the other valve. Length, 12 millim.; width, 13; thickness, 6.

Eifel.

Pecten Hasbachii, nob., Tab. nost., XXXVI. f. 13.

The only fragment we possess of this shell is so incomplete that we cannot determine all the characters of the species, nevertheless it has furnished us with a sufficient number to enable us to distinguish it from all others of the same genus that have yet been found in the older beds, and to decide us to give a representation of it.

The radiating ribs, which were in number from eighteen to twenty, are wide, flattened, and divided into two, three or four, by grooves which continue almost to the beaks. The grooves which separate the ribs are concave, and sometimes have one or two obsolete folds.

Refrath; very rare.

Trigonia? sulcata, Goldf., Tab. nost., XXXVII. f. 6. (See the Note, p. 400.)

We preserve to these bivalve casts the name which Goldfuss has given them, undoubtedly from better specimens than ours, for we should have been led to think them *Cypricardiæ*. They are, however, very characteristic of the grauwacke of the banks of the Rhine. Those which we have from Ems appear to differ in some respects from that of Kemmenau, which has been figured.

Ems, Kemmenau ; common.

Posidonia mytiloides, Goldf.

Under this name we know a small shell of which impressions alone are found in the slates, and which we have been unable fully to determine. It has also been given under the name of *P. myacea*.

Eibach near Dillenburg.

Avicula Goldfussii, nob., Tab. nost., XXXVI. f. 15, 15 *a*.

Shell subtrapezoidal, elongated, very inequilateral, thick, with a keel on each valve, which sets off from the beak, and takes a tortuous direction toward the lower angle. Another, less distinct keel, is placed a little lower, between the former and the cardinal edge. Beaks subterminal, small and very recurved. Hinge straight, rather long and very oblique. Numerous and distinct lines of growth covered the whole shell, and as far as we can judge from the cast which we have represented, they were much finer and more close-set near the beaks.

The absence of all traces of teeth in the hinge, has prevented us from placing these casts among the *Pernæ*, with which they have some analogy in form and thickness. This shell is allied to the *O. Saturni* of Goldfuss, Pl. 116. f. 3.

Paffrath ; rare.

Arca Michelini, nob., Tab. nost., XXXVI. f. 6.

Shell transverse, subquadrilateral, very inequivalve and ventricose. Beaks subterminal, rounded and recurved. Hinge straight. Lower edge parallel with the hinge. Keel very much rounded, setting off from the hinge and becoming attenuated as it takes a direction toward the lower posterior edge. Striæ of growth numerous, distinct, unequal, and slightly undulated.

This species resembles *Arca torulosa*, de Buch (Über Goniatites und Clymenien in Schlesien, Pl. I. f. 12.), but the beaks are more rounded and more recurved, and the shell is more ventricose.

Paffrath ; rare.

Megalodon.

The species of this genus, so numerous, and spread through the beds of Paffrath, are rare everywhere else. There is one at Sötenich, and another ill-defined species has been found at Villmar ; and lastly, at Newton and Bradley in Devonshire is found the *M. cucullatus*, Sow., Min. Con. Tab. DLXVIII., which is still much more abundant at Paffrath.

Megalodon concentricus, nob., Tab. nost., XXXVI. f. 11, 11 *a*.

Shell reniform, very depressed, covered with regular, but indistinct, concentric folds. Beaks subterminal, very small, and recurved. Hinge of the left valve having one much flattened cardinal tooth, divided by a shallow groove. Beyond a second groove which limits this tooth begins a fold, the prolongation of a posterior lateral tooth, which is arcuated, very much elongated and equally divided by a groove, toward the middle of which there is a little pit. Upon the right valve the hinge presents but slightly different characters. A long narrow lateral tooth corresponds to the pit of the other valve. Anterior muscular impression very distinct, oblong, striated, and placed under the beak against the cardinal tooth. Posterior muscular impression unknown. Ligament subinternal. Length, 75 millim.; width, 55 ; thickness, 12.

We place this very rare shell in the genus *Megalodon*, not without hesitation. Its external striæ and its extremely depressed form would have separated it, if it had not appeared to us that in its hinge it came nearer to this than to any other genus.

Paffrath; very rare.

1. *Cypricardia rhombea?*, Phill. Geol. of Yorkshire, Part ii. Pl. V. f. 10.

At Villmar we found an incomplete shell, which appears to be related to *Cypricardia rhombea*; but it is more curved, its keel is more elevated, and its beaks are more terminal.

Villmar; very rare.

2. *Cypricardia elongata*, nob., Tab. nost., XXXVI. f. 14, 14 *a*, 14 *b*.

Shell transverse, very much elongated and very inequilateral, inflated in the middle and obliquely truncated posteriorly, where it is prolonged, forming a rounded angle. Beaks very much recurved and advancing forward over the anterior edge. A rounded keel, setting off from the beak, runs toward the lower posterior angle. The surface of the valves is covered with very fine, numerous, regular and close-set concentric striæ, particularly about the beaks and the anterior edge. Length, 8 millim.; width, 21; thickness, 11.

Although the sections of this shell which we have made have not enabled us to ascertain the details of the hinge with precision, what we have ascertained would not permit us to arrange it with the *Megalodontes*, the cardinal plate being very narrow and the tooth very indistinct.

The *Cypricardia elongata* differs from the *Isocardia Humboldtii* and *Sanguinolaria lamellosa* (Hœninghaus, Goldf., Petref. Tab. CXL. f. 2. p. 207) in being much more elongated, in its beaks being more terminal, and in its more distinct folds being also more regular. Young individuals come nearer in form, being shorter and comparatively wider than in the adult state: but they are less inflated than the *I. Humboldtii*, and their greatest width is in the region of the hinge, instead of being toward the posterior edge. As to the *Sanguinolaria undata* of Count Münster (Beiträge, Tab. XII. f. 27.), it might perhaps appear to be still nearer to the *C. elongata*; nevertheless, that may be distinguished by the form of the upper edge, which, judging from the figure, is simple and rounded, and would be confounded with the posterior edge, while these two parts form a very distinct angle in the *Cypricardia elongata*.

Villmar; very rare.

1. *Cardium aliforme*, Sow., Min. Con. Tab. DLII. f. 2, var. *clathrata*, Goldf., Pl. CXLII. f. 1 *g*, Tab. nost., XXXVI. f. 7, 7 *a*.

We have again figured this shell, which is regarded by Goldfuss as a variety of *C. aliforme*, because the figure given by that author does not express well the two distinguishing characters, and which would have made us regard it as a species, if we had not known intermediate varieties, forming the passage from one to the other. The latter is characterized by two ribs rather stronger than the others, which gives a rectangular limit to the middle and flattened part of the valves. Between these may be seen three, four and even five less distinct, and the whole surface of the shell is covered with fine, close-set, very regular transverse lamellæ, which, passing over the small ribs, form a very elegant decussation.

Paffrath, Eifel.

2. *Cardium palmatum*, Goldf. Petrefacta Germaniæ, Pl. CXLIII. f. 7. *Venericardia retrostriata*, de Buch.

Besides the type of the species figured in the fine work of Goldfuss, we point out the two following varieties which are found in the same localities:—

Var. *a*. Shell more transverse than the preceding, beaks more recurved, ribs more salient and rounded.

Var. *b*. Less inequilateral, ribs flat and narrower than the grooves which separate them.

These different varieties are very abundant in the ferruginous limestones of Oberscheld. *C. palma-*

tum is also found at Adorf in the Duchy of Nassau and in Westphalia, in the limestone of Schubelhammer, in the Fichtelgebirge, and in New Holland.

This shell had been long since called *Venericardia retrostriata* by De Buch; we know not why Goldfuss should have given it another name without referring to it, and without explaining his motive.

3. *Cardium Lyellii*, nob., Tab. nost., XXXVI. f. 8, 8 *a*, 8 *b*.

Shell subtrigonal, elevated, very narrow at its summit, concave anteriorly, angular behind and furnished on each valve with a sharp-edged keel, which sets off from the beaks and runs down to the lower anterior angle. Beaks large, very much turned forward and contiguous. The anterior part of the valves is covered with oblique and sinuous striæ of growth, and the posterior part is ornamented with nine or ten longitudinal ribs, separated by deep striæ. Length, 9 millim.; thickness, 7.

The concavity of the anterior part of this little shell, the size and the curvature of its beaks, the disposition of its posterior ribs, and its general form, distinguish it neatly from *C. mytiloides*, *C. gracile*, and *C. tripartitum* of Münster (see Goldf. Petref. Tab. CXLII. figs. 5, 6, and 10), as well as from the *C. decussatum* and *C. bicarinatum* of Count Münster (Beiträge, Heft iii. Pl. XII. f. 6 and 7).

Villmar; rare.

4. *Cardium Villmarense*, nob., Tab. nost., XXXVI. f. 9, 9 *a*, 9 *b*. Var. *a*, f. 10, 10 *a*.

Shell cordiform, winged, subequilateral, inflated in the middle, prolonged by two appendages, one anterior, broad and thick, the other posterior, short and spine-like. Beaks contiguous, from which set off radiating ribs, which are flattened, alternately salient and depressed, traversed by indistinct but regularly separated concentric striæ. Both the ribs and the striæ are continued, only more attenuated, over the appendages of the valves. Length, 8 millim.; thickness, 7.

Var. *a*. fig. 10, 10 *a*. This lenticular variety is distinguished from the preceding, by its more circular, less ventricose form, and by its constantly much smaller stature.

Villmar; very rare.

5. *Cardium pectunculoides*, nob., Tab. nost., XXXVI. f. 12, 12 *a*.

Shell equilateral, circular, moderately ventricose. Beaks small and nearly contiguous. Wide and slightly elevated concentric folds, which are pretty regular, cover nearly the whole of each valve, and become changed near the edges into rather lamellar and striated folds. On both sides of the beaks near the upper edge are seen some longitudinal, sharp, pretty distinct folds. Hinge unknown.

Oberscheld, Waldeck; common.

1. *Lucina proavia*, Goldf. Petrefacta Germaniæ, Pl. CXLVI. f. 6. Tab. nost., XXXVII. f. 1, 1 *a*.

We have given a new representation of this species, so abundant in the ancient beds of the banks of the Rhine, because the shell figured by Goldfuss is either a variety or a young individual, which will be easily seen upon comparing the two figures. Length, 64 millim.; width, 64; thickness, 28.

Eifel, Lustheide; common.

2. *Lucina antiqua*, Goldf., *loc. cit.*, Pl. CXLVI. f. 7.

A careful examination is requisite to avoid confounding this species with the *L. gibberula* of the lower tertiary beds.

3. *Lucina Dufrenoyi*, nob., Tab. nost., XXXVII. f. 2, 2 *a*.

Shell transverse, subquadrilateral, rounded, subequilateral, regularly ventricose, covered with concentric, unequal and pretty distinct lines of growth. Beaks small, contiguous, inclined forward. Corselet and lunule slightly apparent. Shell thin. Hinge unknown. Length, 40 millim.; width, 53; thickness, 25.

The thinness of the shell, the form of the beaks, and the absence of a posterior fold, have induced us to place this fossil among the *Lucinæ*, until a knowledge of its hinge shall enable us positively to decide †.

We are obliged to M. Puzos for the opportunity of making known this very rare species.

Sötenich.

Sanguinolaria ————?

We refer to this genus a bivalve cast, which in form is related to *S. pygmæa*, Goldf., Pl. CLIX. f. 20. It is of the same size as *S. striata*, Münster (see Goldf., Pl. CLIX. f. 19.).

Villmar; very rare.

Pholadomya Munsteri, nob., Tab. nost., XXXVII. f. 3, 3 *a*.

Shell transverse, securiform, inequilateral, rather sharp-edged in front, inflated in the middle and very compressed and prolonged backward. Beaks rounded, inflated, curved, and contiguous. Concentric folds regular, very distinct, extending from the anterior part of the valves to the posterior depression, where they become attenuated, and disappear altogether far in front of the rostriform angle which terminates the shell. Upper edge concave from the beaks to the rostrum. Lower edge convex. Muscular impressions semilunar, very distinct near the beaks, and placed near the upper edge where the transverse folds terminate. Length, 37 millim.; width, 67; thickness, 30.

This shell is nearly allied to the *Lutraria prisca*, Goldf., Pl. 153. f. 9.

Bensberg, Eifel; rare.

1. *Solen pelagicus*, Goldf. Petref. Germ., Pl. CLIX. f. 2. Tab. nost., XXXVII. f. 5, 5 *a*, 5 *b*.

We have given a representation of the cast of a *Solen*, which appears to be related to the species figured under this name by Goldfuss.

From Lustheide.

2. *Solen Lustheidii*, nob., Tab. nost., XXXVII. f. 4, 4 *a*, 4 *b*.

This species, of which we only know the fragment of a cast, has appeared to us to differ from the preceding sufficiently to warrant us in distinguishing it by another name.

Lustheide; rare.

Ctenocrinus typus, Bronn, N. Jahrb., 1840, p. 542. Tab. nost., XXXVII. f. 7.

We have also figured this remarkable Crinoidal fossil from the grauwacke of the duchy of Nassau, to show the pinnules or tentacles of the fingers, which could not have been visible on the specimen which Bronn has figured.

At the foot of the Hausling near Arnsberg, and near Ems.

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† Many of the true *Lucinæ* have a posterior fold; further, it is not by the hinge that we can decide a *Lucina*, but by the muscular impressions. (Remark by Mr. G. Sowerby, the Translator of the Descriptions of the Fossils.)

[For an account of some of the Silurian Fossils of the Rhenish Provinces see Mr. J. de Carle Sowerby's description, Appendix *posteà*, p. 408.]

Note to the Table commencing page 380.

The capitals which follow the names of the places in the column "Localities in Europe," are introduced to distinguish the system which occurs at these points: e. g. *Orthoceratites calamiteus*. Wissenbach, S., Chimay, Refrath, &c., D., signify that Wissenbach stands on the Silurian system; Chimay, &c. on the Devonian. The letter C. signifies Carboniferous System. Where the localities belong to one system no letter is given, the system being easily determined by referring to columns 4–8.

Tabular List of the Organic Remains of the Devonian System in Europe, together with the Species of the Silurian and Carboniferous Systems in the Rhenish Provinces.

The following abbreviations of authors' names and works are employed in the Table.

Ag. Agassiz, Recherches sur les Poissons Fossiles; *id.* in the Silurian Syst. by R. I. Murchison.—*Be.* Beck (collection).—*Beyr.* Beyrich, Rheinische Überg. Verstein. Goniatites; *id. Verst. Rhein.* Versteinerungen des Rhein. Übergangs-Gebirges.—*de Bl.* de Blainville, Man. de Malacologie; *id.* Man. d'Actinologie.—*Blum.* Blumenbach, Arch. Telluris.—*Bock.* Verhandl. des Vaterländ. Museums in Böhmen, 3 Heft, 1825, und v. j. 1833.—*Bosc.* Bosc. Conchyl.—*Bra.* Braun. Jahrb. für Min. 1838.—*Brong.* Alexandre Brongniart, Hist. Nat. Crust. Fos.—*Bronn*, Lethæa Geognostica; *id. Jah. für Min.* Jahrbuch für Mineralogie, Geognosie, &c.; *id. Tasch.* Taschenbuch, &c.—*de B.* de Buch, Über Ammoniten und Goniatiten; *id.* Über Terebrateln. Transl. Mém. Soc. Géol. France, t. iii.; *id.* Über Delthyris oder Spirifer und Orthis, Transl. Mém. Soc. Géol. France, t. iv.; *id. Ub. Gon. und Clym. Schl.* Über Goniatiten und Clymenien in Schlesien; *id. Beitr. Geb. Rus.* Beiträge zur Bestim. der Gebirge. in Russland.—*Conr.* Conrad, States Report, New York, 1840.—*Dalm.* Dalman, Über die Paläaden, &c.; *id.* Terebratuliter, &c.—*Defr.* Defrance, Dict. Sc. Nat.—*Ehr.* Ehrenberg. Berl. Trans.—*Eichw.* Eichwald, Zoologia Specialis and Silurische System in Esthland.—*Emm.* Emmerich, De Trilobitis Dissertatio Inaug.—*Fisch.* Fischer de Waldheim, Oryc. Gouvern. Moscou.—*Fer.* de Férussac. Monog. Cephal. —*Flem.* Fleming, Hist. Brit. Anim.—*Gmel.* Gmelin, Edit. Syst. Nat.—*Gold.* Goldfuss, Petrefacta Germaniæ; *id. Dech.* translation Geol. Man. of De la Beche by Dechen; *id. Nov. Act. Acad.* Nova Acta Academiæ Cæs. Leop. Cur. Nat. t. xix.; *id. Bonn Mus.* in Museum of Bonn.—*Gre.* Green, Monag. Trilob. N. Amer.—*H. v. Mey.* Hermann von Meyer, Nov. Act. Acad. Cæs. Leop. Nat. Cur. t. xv.—*Hœn.* Hœninghaus in Geol. Man. by De la Beche (French translation), also Verst. Sammlung, H. iii.—*His.* Hisinger, Lethæa Suecica.—*Hüp.* de Hüpsch, Natur. Nieder Deutschl., also Obser. sur la Phys. t. iii.—*Kn.* Knorr, Recueil des Monum.—*Kön.* König, Icon. Fos. Sect.—*de Kon.* de Koninck, tabular list (manuscript).—*De la B.* De la Beche, Geol. Man. (French translation).—*Lam.* de Lamarck, Hist. Anim. sans Vert.—*Lamour.* Lamouroux. Exp. Method.—*Lev.* Leveillé, Mém. Soc. Géol. France, t. ii.—*Lin.* Linnæus, Syst. Nat. Edit. Gmelin.—*Lonsd. Sil. Syst.* in Murchison's Silurian Syst.; *id. Dev. Syst.* On the Struct. of Devon by Sedgwick and Murchison.—*Mart.* Martin. Pet. Derbin.—*Mill.* Miller, Nat. Hist. Crin.—*Mil. Ed.* Milne Edwards, 2nd edit. of Lamarck.—*Min. C.* Mineral Conchology by J. Sowerby.—*Montf.* Denis de Montfort. Conchylogie.—*de Münst. Abh.* 1832, Abhandlung über Planuliten und Goniatiten, 1832; *id. Beitr. H.* 1, 1839, Beiträge zur Petrefactenkunde, Heft i. 1839; *id. Beitr. H.* iii. 1840, Beitr. Petref. Heft iii. 1840.—*Murch.* Murchison in the Silurian Syst.; *id. Bul. de la Soc. Géol.* Bulletin de la Société Géologique de France, t. xi.—*d'Orb.* Alc. d'Orbigny, Monogr. des Céphalopodes.—*Pand.* Pander, Beit. z. Geog. Rus. Reiches.—*Pent.* Pentland, Geol. Trans. 2nd Series, vol. iii.—*Phill.* Phillips, Geology of Yorkshire, Part 2.; *id. Pal. Fos.* Figures and Descriptions of the Palæozoic Fossils, &c.—*Quenst.* Quenstedt on Trilobites, Wiegmann's Archiv. iii. H. 1.—*Raf.* Rafinesque.—*Schlot.* Schlotheim, Petrefactenk. und Wis. 1827.—*Schröt.* Schröter, Einleit. Gesch. Verst.—*Sow. Sil. Syst.* J. de C. Sowerby in the Silurian Syst. by Murchison; *id.* Geol. Trans. vol. v. On the Physical Structure of Devon by Sedgwick and Murchison.—*G. Sow.* George Sowerby in this memoir.—*Stein.* Steininger, Bemerkungen über, &c. 1831, Mém. de la Soc. Géol. de France, t. i.; *id.* Bull. Géol. Soc. France, t. viii. ix.—*Val.* Valenciennes, Geol. Trans. 2nd Series, vol. iii.—*Vern.* de Verneuil, Bull. Soc. Géol. France, t. xi.—*Wahl.* Wahlenberg, Petrificata Telluris Suecanæ, Nov. Act. Reg. Soc. Sc. Upsal. t. viii.

N.B.—The species', systems', or localities' names followed by the sign ? are considered doubtful.

As some of the localities introduced into the following Table may not be familiar to every reader, it has been thought advisable to prepare an alphabetical list of them, accompanied by such general directions as will enable the locality to be easily found. (Ed.)

Abenththaeur	Prussia	Hündsruck, Lower Rhine.
Abergavenny	England.	Monmouthshire.
Adorf	Principality of Waldeck.	S.S.W. of Stadtberg.
Adsel	Russia	Government of Livonia.
Aggerthal	Prussian Westphalia	N.E. of Bonn.
Aland	Russia	Gulf of Bothnia.
Altenahr	Prussia	Lower Rhine.
Amay	Belgium	4½ leagues S.W. of Liège.
Angers	France	Depart. of Maine and Loire.
Ashburton	England	Devonshire.
Aymestry	England	Herefordshire.
Arnsberg	Prussian Westphalia	On the Rhur.
Auberlahnstein	Duchy of Hesse	Near Mayence.
Babbacombe	England	S. Devonshire.
Baggy Point	England	N.W. of Devonshire.
Bain	France	Brittany.
Barnstaple	England	Devonshire.
Barton	England	S. Devonshire.
Bellignies	France	Depart. du Nord.
Bensberg	Prussian Westphalia	Rhine, opposite Cologne.
Berendorf	Prussia	District of the Eifel.
Beringhausen	Prussian Westphalia	S. W. of Stadtberg.
Berry Pomeroy	England	S. Devonshire.
Blankenheim	Prussia	District of the Eifel.
Bolland	England	West Riding, Yorkshire.
Bradley	England	Devonshire.
Borenshult	Sweden	East Gottland.
Braubach	Duchy of Nassau	South of the Lahn's mouth.
Bredlar	Prussian Westphalia	Between Brilon and Stadtberg.
Brilon	Prussian Westphalia	70 miles E.N.E. of Cologne.
Brushford	England	North of Devonshire.
Buregi	Russia	South shore of Lake Ilmen.
Buxton	England	Derbyshire.
Cannington Park	England	N. Devonshire.
Caithness	Scotland	Eastern Coast.
Chaudfontaine	Belgium	2 leagues S.S.E. of Liège.
Chircombe Bridge	England	S. Devonshire.
Choquier (Chokier)	Belgium	Province of Liège.
Chudleigh	England	S. Devonshire.
Coalbrook Dale	England	Shropshire.
Cornden	England	Near Shelve, Shropshire.
Couvin	Belgium	Province of Namur.
Combe Martin	England	N. Devonshire.
Combe	England	S. Devon., near Ashburton.
Croyde Bay	England	N. Devonshire.
Cronenburg	Prussia	District of the Eifel.
Chidrova	Russia	Banks of the Dwina.
Dago Island	Esthonia	Entrance Gulf of Finland.
Darlington	England	S. Devonshire.
Daun	Prussia	Duchy of the Lower Rhine.
Dietz	Duchy of Nassau	Left bank of Lahn.
Delbury	England	Shropshire.
Dinas Cove	England	Cornwall.
Dollendorf	Prussia	District of the Eifel.
Dombrowa	Russian Poland	22 miles W. of Grodno.
Donetz	Russia in Europe	Govern. Ekaterinoslav.
Drolshagen	Westphalia	E. of Cologne.
Dorpat	Russia	Livonia.
Dudley	England	Worcestershire.
Dürrewald	Bavaria	Near Geroldsgrün.
Ebersdorf	Silesia	Co. of Glatz.
Ehrenbreitstein	Nassau	Rhine, opposite Coblentz.
Eibach	Duchy of Nassau	Near Dillenburg.
Eifel	Prussia	Lower Rhine.
Elberfeldt	Westphalian Prussia	18 miles E. of Dusseldorf.
Elbersreuth	Bavaria	Between Gerolsgrün and Presseck.
Ems	Duchy of Nassau	Near mouth of the Lahn.
Essen	Prussian Westphalia	16 miles N.N.E. Dusseldorf.
Falckenberg	Silesia	Foot of the Eulengebirge.
Faou	Bretagne	North of Brest.
Fedotova	Russia	Government of Archangel.
Felindre	England	Near Knighton, Radnorsh.
Ferques	France	Near Boulogne.
Feugeurolles	France	Near Caen.
Florence Court	Ireland	C. Fermanagh, nr. Enniskillen.
Fowey	England	Cornwall.
Frankenberg	Hesse Cassel	On the Eder, S. W. Cassel.
Fresh Water, East.	England	Pembrokeshire.
Gamrie	Scotland	County of Banff.
Geigen	Bavaria	Near Hof.
Gerlas	Bavaria	Near Geroldsgrün.
Gattendorf	Bavaria	Near Hof.
Gerolstein	Prussia	District of the Eifel.
Geroldsgrün	Bavaria	To the W. of Hof.
Geiser	Bavaria	Near Hof.
Geslar	Hanover	The Hartz.
Gladbach	Prussia	Pro. Juliers, near Müllheim.
Golzines	Belgium	Province of Namur.
Greifenstein	Duchy of Nassau	S. of Dillenburg.
Groningen	Holland	Northern Province.
Grundt	Hanover	West of the Hartz.
Grunenwald	Prussia	District of the Moselle.
Gimborn	Westphalia	S.E. of Wipperfurth.
Hal	Belgium	Province of Limbourg.
Hardrow	England	Yorkshire.
Hagen	Prussian Westphalia	East of Dusseldorf.
Halberton	England	Devonshire.
Haüsling	Duchy of Nassau	Hill, near Arnsberg.
Heissenstein	Westphalia	Kreise of Siegen.
Hagginton, West	England	N. Devonshire.
Heisterstein	Prussia	District of the Eifel.
Horeb Chapel	England	Brecknockshire.
Herborn	Prussia	Duchy of Nassau.
Hillsborough	England	N. Devonshire.
Hoffnung	Westphalia	On the Ruhr.
Horderley	England	Shropshire.
Hof	Bavaria	22 miles N.N.E. Bayreuth.
Houffalize	Belgium	10½ leag. N.E. of Luxembourg.
Hope	England	S. Devon., near Torquay.
Hübigenstein	Hanover	The Hartz, near Clausthal.
Hundsruck	Prussia	Lower Rhine.
Huy	Belgium	6¾ leagues S.W. of Liège.
Ilfracombe	England	N. of Devonshire.
Iserlohn	Prussian Westphalia	41 miles E. of Dusseldorf.
Isle of Arran	Scotland	West Coast.
Isborsk	Russia	Government of Pskof.
Izé	France	Department d'Ile et Vilaine, near Vitre.
Keldenich	Prussia	Lower Rhine, in the Eifel.
Kemmenau	Duchy of Nassau	Near Ems.
Kendal	England	Westmoreland.
Kerliver	France	14 miles E. by S. of Brest.
Kosorr-Branitz	Bohemia	Banks of the Moldau.
Kirkby-Lonsdale	England	Westmoreland.
Kulkeagh	Ireland	County of Fermanagh.
Lahn River	Prussia	Duchy of Nassau.
Lake Ilmen	European Russia	Government of Novgorod.
Lahnstein	Duchy of Nassau	Mouth of the Lahn.
Landerskron	Prussia	Near Siegen.
Landlake	England	S. Devonshire.
Langenaubach	Nassau	Near Dillenburg.
Lattunaudière	France	Dep. Loire Inf., nr. Nantes.
Leary	England	S. Devonshire.
Lew-Trenchard	England	S. Devonshire.
Lethmate	Westphalia	On the Lenne.
Linton	England	N. of Devonshire.

Limbourg	Belgium	Province of Liège.
Lindlar	Westphalia	N.E. of Cologne.
Llandovery	Wales	Caermarthenshire.
Longueville	Shropshire	On the river Onny.
Long-Hope	England	Gloucestershire.
Ludlow	England	Shropshire.
Luga	Russia in Europe	97 miles S. of St. Petersburg.
Lustheide	Right bank of the Rhine	Near Cologne.
Marwood	England	N. of Devonshire.
May	France	Near Caen.
Martelange	Duchy of Luxembourg	On the Moselle.
Martenberg	Prussian Westphalia	Principality of Waldeck, near Stadtberg.
Marienheide	Prussian Westphalia	N.E. of Cologne.
Malmö	Sweden	18 m. E.S.E. Copenhagen.
Meschede	Westphalia	On the Ruhr.
Mettman	Westphalia	E. of Dusseldorf.
Meadsfoot Sands	England	S.E. of Devonshire.
Mondrepuis	France	Dep. of the Aisne.
Morebath	England	Devonshire.
Moulton	England	Yorkshire.
Mudstone Bay	England	S. Devonshire.
Mülcke	Silesia	Near Hausdorf.
Mendip Hills	England	Somersetshire.
Miatchkova	Russia	Government of Moscow.
München-Mühle	Nassau	Left bank of Lahn.
Namur	Belgium	Province of Namur.
Néhou	France	Normandy, la Manche.
Newton Bushell	England	S. Devonshire.
Niederosbach	Nassau	Mouth of the Lahn.
Nieder-Ehe	Lower Rhine	In the Eifel.
Oberscheld	Duchy of Nassau	Near Dillenburg.
Oberschulenberg	Bavaria	Near Clausthal.
Ogwell	England	S. of Devonshire.
Olpe	Prussian Westphalia	E. of Cologne.
Olne	Belgium	4 leagues E.S.E. of Liège.
Onny River	England	Shropshire.
Otterburn	England	Northumberland.
Padstow	England	Cornwall.
Paffrath	Prussian Westphalia	N.E. of Cologne.
Pelm	Prussia	District of Eifel.
Peredki	Russia	Valdaï Mountains.
Pilton	England	N. Devonshire.
Pinega	Russia	78 miles E. by S. of Archangel.
Petherwin, South	England	Cornwall.
Pokroi	Russia	Government of Lithuania.
Podolsk	Russia	Government of Moscow.
Powis Castle	Wales	near Welchpool.
Prussino	Russia in Europe	Near the Volkof.
Presseck	Bavaria	S. W. of Hof.
Prüm	Prussia	District of the Eifel.
Pskof	Russia	224 miles S.S.W. of St. Petersburg.
Radnor Forest	England	Radnorshire.
Rammelsberg	Hanover	The Hartz, near Goslar.
Ratingen	Prussian Westphalia	N.E. of Dusseldorf.
Ratofka	Russia	Government of Moscow.
Regnitzlosau	Franconia	Near Hof.
Refrath	Prussian Westphalia	E. of Cologne.
Revel	Russia	Gulf of Finland (Esthonia).
Rebinghausen	Prussia	Lower Rhine, in the Eifel.
Rhisne	Belgium	Near Namur.
Rocquigny	France	Dep. Ardennes.
Runderoth	Prussian Westphalia	East of Cologne.
Sablé	France	Dep. of the Sarthe.
Sapey	England	Worcestershire.
Saunton	England	N. of Devonshire.
Scarlett	England	Isle of Man.
Schidilofka	Russia	Government of Novgorod (Lake Ilmen).
Schwarzenbach	Bavaria	Fichtelgebirge, near Hof.
Schwelm	Westphalia	E. of Dusseldorf.
Schübelhammer	Bavaria	Near Elbersreuth.
Settle	England	West Riding, Yorkshire.
Serebrianka	W. flanks of Ural	Tributary of the Tchussavaya.
Serpoukhof	Russia in Europe	93 versts S. of Moscow.
Schelke	Westphalia	N.E. by E. of Dusseldorf.
Sharkham	England	S. Devonshire.
Siegen	Prussian Westphalia	S.S.E. of Cologne.
Solingen	Prussian Westphalia	20 miles E. of Cologne.
Sötenich	Prussia	Lower Rhine, banks of the Lahn.
Siebengebirge	Prussia	Lower Rhine, near Bonn.
Steinlacke	Nassau	Near Weilburg, on the Lahn.
Stolberg	Prussia	Lower Rhine, 3 miles S.S.W. of Eschweila.
Stolobinskoi	Russia	Valdaï Hills.
St. Sauveur le vicomte.	France	Depart. de la Manche.
Sunnbridge	England	N. Devonshire.
Sülbach	Hanover	The Hartz.
Taunus	Nassau	Between the Lahn and Mayne.
Tchudovo	Russia	80 miles S. of Petersburg.
Tin Mill	Scotland	Caithness.
Tintagel	England	Cornwall.
Torquay	England	Devonshire.
Tournay	Belgium	Province of Hainault.
Truscott	England	S. Devonshire.
Valdaï Mountains	Russia in Europe	Between Moscow and Smolensk.
Vereïa	Russia	Government of Moscow.
Verviers	Belgium	15 miles S. by S. of Liège.
Vilna Riv.	Russia	Government of Lithuania.
Villmar	Duchy of Nassau	Left bank of the Lahn.
Visé	Belgium	Province of Liège.
Vitchedga River	European Russia	Near the N. Ural.
Venn	England	N. Devonshire.
Vitegra	Russia	S. side of Lake Onega.
Volkof	Russia	Tributary of Lake Ladoga, Govern. of Novgorod.
Unkel	Right banks of the Rhine	Westphalia.
Voroneje	Russia	Chief town of Government.
Watersmeet	England	N. of Devonshire.
Wenlock	England	Shropshire.
Welshpool	Wales	Montgomeryshire.
Westerwald	Duchy of Nassau	N. of the Lahn.
Westleigh	England	N. of Devonshire.
Werden	Westphalia	On the Ruhr.
Wetzlar	Duchy of Nassau	On the Lahn.
Whitesand Bay	England	S. Devonshire.
Whitbach	England	Shropshire, near Ludlow.
Whitewell	England	West Riding of Yorkshire.
Wiltz	Belgium	Duchy Luxembourg.
Wipperfurth	Westphalia	S.W. of Dusseldorf.
Wissenbach	Duchy of Nassau	N.W. of Wetzlar.
Woodabay	England	N. Devonshire.
Yealm Bridge	England	S. Devonshire.
Yealmpton	England	S. Devonshire.
Zaraïsk	Russia in Europe	Government of Riazan.

Note.—We are indebted to the kindness of Sir Philip Grey Egerton for this list of the Devonian fishes, which, including some species named by Agassiz, in the splendid collection of that distinguished geologist, and not yet published, is necessarily more complete than the one we had prepared. It is the best for the present time, though it does not perhaps contain all the species named by Agassiz in his last visit to Scotland, Sir Philip Grey Egerton not having had the opportunity of examining the Scotch collections since that time.

No. of Species.	Genera and Species.	Authors and References. The numerals refer to Species described and figured in this Memoir.	Sil. Sp. in Rhen. Prov.	Dev. & Sil. Sp.	Devonian Sp.	Dev. & Carb. Sp.	Carb. Sp.	Localities in Europe.	Elsewhere.
	PISCES.								
	Placoid Order.								
1.	Ctenacanthus ornatus	Agass. Poiss. Foss. vol. iii. p. 12; Murch. Sil. Syst.	...	...	*	...	...	Worcestershire.	
1.	Onchus arcuatus	id. ib. vol. iii. p. 7; ib.	...	...	*	...	...	Herefordshire, &c.	
2.	— semistriatus	id. ib. vol. iii. p. 8; ib.	...	...	*	...	...	ib.	
1.	Ptychacanthus, n. s.	Murch. Sil. Syst. p. 597.	...	...	*	...	...	ib.	
	Ganoid Order.								
1.	Cephalaspis Lewisii	Agass. Poiss. Foss. vol. ii. p. 149; Murch. Sil. Syst.	...	...	*	...	...	ib.	
2.	— Lloydii	id. ib. vol. ii. p. 150; id. ib.	...	...	*	...	...	ib.	
3.	— Lyellii	id. ib. vol. ii. p. 142; id. ib.	...	...	*	...	...	Forfarshire, Herefordshire.	
4.	— rostratus	id. ib. vol. ii. p. 148; id. ib.	...	...	*	...	...	Herefordshire, &c.	
1.	Cheiracanthus microlepidotus.	id. Manuscript	...	...	*	...	...	Morayshire, Lethen Bar.	
2.	— minor	id. Poiss. Foss. vol. ii. p. 127.	...	...	*	...	...	Orkney.	
3.	— Murchisoni	id. ib. vol. ii. p. 126.	...	...	*	...	...	Gamrie, Banffshire.	
1.	Cheirolepis Cummingiæ.	id. Manuscript	...	...	*	...	...	Morayshire, Lethen Bar.	
2.	— Traillii	id. Poiss. Foss. vol. ii. p. 130.	...	...	*	...	...	Orkney.	
3.	— uragus	id. ib. vol. ii. p. 132.	...	...	*	...	...	Gamrie, Banffshire.	
1.	Coccosteus cuspidatus	Miller's Old Red Sandstone, Plate III.	...	...	*	...	...	Rosshire and Cromarty.	
2.	— latus	Trans. R. S. Edinburgh, vol. xv. p. 90; Miller, p. 57.	...	...	*	...	...	Rosshire, Cromarty, Orkney.	
3.	— oblongus	Agass. Manuscript, Miller's Old Red Sandstone, p. 57.	...	...	*	...	...	Morayshire, Lethen Bar.	
4.	— n. s.?	Miller's Old Red Sandstone, p. 57.	...	...	*	...	...	?	
5.	— (species not yet determined)	...	...	...	...	...	...	Courland, Livonia, Eifel.	
1.	Dendrodus biporcatus	Owen, Microscopic Journal, vol. i. No. 1. p. 4.	...	...	*	...	...	Scatt's Craig, near Elgin.	
2.	— compressus	id. ib. vol. i. No. 2. p. 17.	...	...	*	...	...	ib.	
3.	— sigmoideus	id. ib.	...	...	*	...	...	ib.	
4.	— strigatus	id. ib.	...	...	*	...	...	ib.	
5.	— new species	...	...	...	*	...	...	Livonia, Russia,	
1.	Diplacanthus crassispinus.	Agass., Trans. R. S. Edinb. vol. xv. p. 90; Diplocanthus crassispinus, Traill.	...	...	*	...	...	Orkney.	
2.	— longispinus	id. Manuscript	...	...	*	...	...	Morayshire, Lethen Bar.	
3.	— striatulus	id. ib.	...	...	*	...	...	ib.	
1.	Diplopterus borealis	id. ib.; Trans. R. S. Edinb. vol. xv. p. 90; Diplopterus Agassizi, Traill.	...	...	*	...	...	Orkney.	
2.	— macrocephalus	id. ib.	...	...	*	...	...	Morayshire, Lethen Bar.	
3.	— Agassizi	Traill, Trans. R. S. Edinb. vol. xv. p. 89.	...	...	*	...	...	Pomona (Orkney).	
1.	Dipterus macrolepidotus.	Valenciennes, Agass. Poiss. Foss. vol. ii. p. 115; Murch. Sil. Syst.	...	...	*	...	...	Caithness, Herefordshire.	
1.	Glyptolepis leptopterus.	Agass. Manuscript, Miller's Old Red Sandstone, p. 82.	...	...	*	...	...	Morayshire, Lethen Bar.	
2–4.	Three species	Miller's Old Red Sandstone, p. 82.	...	...	*	...	...	Cromarty.	
1.	Holoptychus nobilissimus.	Murch. Sil. Syst. p. 599; Miller, p. 162; Gyrolepis giganteus, Agass.	...	...	*	...	...	Perthshire, Scatt's Craig, Morayshire, Lake Ilmen, Vitegra, Valdaï, Livonia, Courland, Voroneje.	Blossburg, county of Tiogo in Pennsylvania; Genesseeriver; Allghang in New York.
2.	— Omaliusii	(Agass. ined.)	...	...	*	...	...	Belgium.	
3.	— indet.	Phil. pal. fos. 57. f. 256, 257.	...	...	*	...	...	Devonshire.	
1.	Acanthodes	Miller	...	...	*	...	...	Scotland.	
1.	Osteolepis arenaceus	Agass. Poiss. Foss. vol. ii. p. 122.	...	...	*	...	...	Gamrie, Banffshire.	
2.	— macrolepidotus	Val. and Pentl.; id. ib. vol. ii. p. 119.	...	...	*	...	...	Orkney, Caithness.	
3.	— major	Agass. Manuscript.	...	...	*	...	...	Morayshire, Lethen Bar.	
4.	— microlepidotus	Val. and Pentl.; Agass. Poiss. Foss. vol. ii. p. 121.	...	...	*	...	...	Orkney, Caithness.	
1.	Platygnathus paucidens.	Agass. Manuscript; Trans. R. S. Edinb. vol. xv. p. 90.	...	...	*	...	...	Orkney.	

No. of Species.	Genera and Species.	Authors and References. The numerals refer to Species described and figured in this Memoir.	Sil. Sp. in Rhen. Prov.	Dev. & Sil. Sp.	Devonian Sp.	Dev. & Carb. Sp.	Carb. Sp.	Localities in Europe.	Elsewhere.
1.	Pterichthys cornutus.	Agass. Manuscript	...	...	*	...	...	Morayshire, Lethen Bar.	
2.	— latus	Agass. Manuscript.	...	...	*	...	...	Morayshire, Lethen Bar.	
3.	— Milleri	Agass., Miller, Report Brit. Assoc., 1840, p. 99.	...	...	*	...	...	Orkney, Cromarty.	
4.	— productus	Agass. Manuscript	...	...	*	...	...	Morayshire, Lethen Bar.	
5.	— n. s.	Miller's Old Red Sandstone, p. 51.	...	...	*	...	...	Cromarty.	
6.	— n. s.	id. ib.	...	...	*	...	...	ib.	
	Crustacea.								
1.	Calymene articulata.	Münst. Beitr. 1840. 5. f. 7.	...	...	*	...	...	Elbersreuth.	
2.	— Blumenbachii	Brong. 1. f. 2; Murch. Sil. Syst. 7. f. 5–7; Dalm. 1. f. 3; Buckl. Bridgew. Treat. 46. f. 1–3; His. 1. f. 3. 4.	*	...	...	...	...	Wissenbach, Daun, Cotentin, Angers, Gottland, Oeland, Scania, East Gottland, Dalecarlia, Shropshire.	Mount of Cedar in South Africa; the most common of Trilobites in the United States. State of the Ohio, at Trenton Falls, in Perry county, Tennessee, &c. &c.
3.	— concinna	Dalm. 1. f. 5; His. 1. f. 10. (Proteus Cuvieri. Stein. 21. f. 6.)	...	*	*	*	*	Gottland, S.; Eifel, D., Mülke near Hausdorf, C.	
4.	— æqualis	Herm. von M. (C. concinna, aff.) Jahr. für Min. 1833. p. 483; N. Acta Cæs. 1831.	...	...	...	...	*	Herborn.	
5.	— granulata	Münst. Beitr. 1840. 5. f. 3; Phil. pal. fos. 56. f. 248; Sow. Geol. Trans. t. v. 54. f. 23, 24.	...	...	*	...	...	Presseck, Schübelhammer, Oberscheld? Torquay, Petherwin.	
6.	— intermedia	Münst. Beitr. 1840. 5. f. 2.	...	...	*	...	...	Elbersreuth.	
7.	— Latreillei	Stein. p. 351; Phil. pal. fos. 56. f. 249	...	...	*	...	...	Eifel, Staunton, Pilton, Brushford, Hope, Barton, Devonshire.	
8.	— id. var. *a.*	Bronn, Jahr. für Min. 1825. an C. latifrons.	...	...	*	...	...	Eifel.	
9.	— lævis	Münst. Beitr. 1840. 5. f. 4; Phil. pal. fos. 55. f. 250; Sow. Geol. Trans. vol. v. 53. f. 12–15.	...	...	*	...	...	Elbersreuth, Brushford, Mudstone Bay, Newton, &c.	
10.	— macrophthalma—	Br. 1. f. 4, 5; Murch. Sil. Syst. 14. f. 2; C. bufo, Green, Monog. Tril. N. Amer.; Phacops macrophthalmus, Emmerich, de Trilobitis Dissertatio Inauguralis; Cal. Schlotheimi, Bronn, Jahr. für Min. 1825; Stein. p. 352=C. Brongniartii, Stein. 21. f. 4.	*	*	*	...	...	Grauwacke of the Eifel, Wissenbach, Wenlock, Sweden, Prague, Revel, St. Petersburg, S.	Berkley (Virginia).
11.	— propinqua	Münst. loc. cit. 5. f. 6, an C. Sternbergii?	...	...	*	...	...	Elbersreuth.	
12.	— Sternbergii	Bock. verh. der vat. museum, H. 3. 1829. t. 1. f. 5; Münst. loc. cit. 5. f. 5; Phil. pal. fos. 56. f. 247.	...	...	*	...	...	Barton, Elbersreuth, Prague.	
13.	— subvariolaris	id. 5. f. 1. an C. variolaris? Brong.	...	...	*	...	...	Elbersreuth.	
14.	— Tristani	Brong. 1. f. 2.	*	...	...	...	...	Prüm, Cotentin, La Hunaudière (Bretagne).	Mount of Cedar in South Africa.
1.	Homalonotus Herschelii.	Murch. Sil. Syst. 7 bis. f. 2	*	...	...	...	...	Daun, mouth of the Lahn, Revel?, Shropshire.	Mount of Cedar in South Africa.
2.	— Knightii	Kön. Icon. Fos. Sec. 7. f. 85; Murch. Sil. Syst. 7. f. 1, 2; Phil. pal. fos. 57. f. 253.	*	*	*	...	...	Ludlow, Néhou, Wissenbach, Braubach, Daun, Ehrenbreitstein, Martelange, Altenahr, banks of the Rhine, Ahr and Lahn, S., Torquay, D.	
1.	Asaphus brevis	Münst. Beitr. 1840. 5. f. 10.	...	...	*	...	...	Schübelhammer (Clym. lim.), Presseck.	
2.	— Cawdori	Murch. Sil. Syst. 7. f. 9.	...	*	*	...	...	Fresh Water East, S., Schübelhammer, D.	
3.	— grandis	Münst. loc. cit. 9. f. 1.	...	...	*	...	...	Elbersreuth.	
4.	— granuliferus	Phil. Geol. Yorks. pt. ii. 22. f. 7; id. pal. fos. 56. f. 251.	...	...	*	*	...	Torquay, D., Yorkshire, Tournay, C.	
5.	— Hausmannii	Brong. 2. f. 3; Sternb., Schlot.	*	...	...	...	...	Kemmenau, Prague, bank of the Moldau at Kosorr-Branitz, Kalstein.	New York, banks of Lake Erie.
6.	— pusillus	Münst. loc. cit. 5. f. 9.	...	...	*	...	...	Schübelhammer, Presseck.	
7.	— subtyrannus	nob. *antè*, p. 336	*	...	...	...	...	Wissenbach.	
8.	— indeterm.	Phil. pal. fos. 55. f. 252.	...	...	*	...	...	Hope, near Torquay.	
1.	Bumastus Franconicus.	Münst. Beitr. 1840. 5. f. 17	...	...	*	...	...	Elbersreuth.	
2.	— planus	id. ib. f. 18	...	...	*	...	...	ib.	
1.	Paradoxides brevimucronatus.	id. ib. f. 12	...	...	*	...	...	ib.	
1.	Illænus crassicauda	Dalm., Palæad. 5. f. 2; His. 3. f. 5; Il. Esmarkii, Schlot. Isis, 1829; I. perovalis, Murch. Sil. Syst. 23. f. 7*a*, *b*; Münst. Beitr. 3. 5. f. 11.	...	*	*	...	...	Cornden near Shelve, Dalecarlia, East Gottland, Porlosk, St. Petersburg, Christiania, Sweden, Bain, Bretagne, S., Presseck, D.	
2.	— triachantus	Gold. Nov. Act. Acad. t. xix. 33. f. 4.	...	...	*	...	...	Eifel.	

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1.	Agnostus pisiformis..	Brong. 4. f. 4; Murch. Sil. Syst. 25. f. 16; Battus, id.; Dalm., Palæad. 6. f. 5; His. 4. f. 5; Münst. Beitr. H. 3. 1840, p. 47.	.....	*	*	...	...	Near Builth, Sweden, S., Elbersreuth, D.	
1.	Brontes costatus.....	Münst. ib. 5. f. 14.	.....	...	*	...	...	ib.	
2.	— flabellifer	Gold. Act. Acad. t. xix. 33. f. 3; Phil. pal. fos. 57. f. 254; Olenus id. Stein. and auct. Goldius, Kon., crust. foss. Belg. Acad. Brux. vol. xiv. 1. f. 1; affinis B. radiatus, Münst.	.....	*	*	...	...	Upper Ludlow, S., Newton, Chimay, Couvin, Eifel, Néhou, Mettmann, Lethmate, D.	Bogoslofsk.
3.	— Neptuni	Münst. ib. 5. f. 16.	.....	...	*	...	...	Elbersreuth.	
4.	— radiatus	id. ib. f. 13.....	.....	...	*	...	...	ib.	
5.	— subradiatus	id. ib. f. 15.	.....	...	*	...	...	ib.	
1.	Harpes speciosus ...	id. ib. f. 19.	.....	...	*	...	...	ib.	
2.	— macrocephalus ...	Gold. Nov. Act. Acad. 33. f. 2; Phil. pal. fos. 55. f. 246. p. 2.	.....	...	*	...	...	Barton, Eifel, Oberscheld.	
1.	Olenus punctatus ...	Stein. 21. f. 1; Calym. arachnoides, Hœningh. Letter, 1835.	.....	...	*	...	...	Eifel.	
1.	Arger armatus	Gold. Nov. Act. Acad. t. xix. 33. f. 1. Asaphus, id. and Bucephalus, id. in De la Beche's Geol. Man. Germ. Tr. by Von Dech. p. 539.	.....	...	*	...	...	ib.	
1.	Bostrichopusantiquus	Gold. loc. cit. suprà, 32. f. 6.	.....	...	...	...	*	Herborn.	
	Cephalopoda.								
1.	Goniatites acutus ...	Münst. Beitr. H. 3. 16. f. 11.	.....	...	*	...	...	Elbersreuth.	
2.	— angustiseptatus ...	id. Abh. 1832. p. 18.....	.....	...	*	...	...	ib. Dürrewald, near Geroldsgrün.	
3.	— angustus.....	id. Beitr. H. 1. p. 28.....	.....	...	*	...	...	Schübelhammer.	
4.	— arquatus.....	id. ib. 18. f. 4. p. 27.....	.....	...	*	...	...	ib.	
5.	— Beaumontii	id. ib. p. 23	.....	...	*	...	...	Gattendorf.	
6.	— Becheri	Gold., Dech., Buch. goniat. 2. f. 2; Beyr. 1. f. 7, 8.	.....	...	*	...	...	Eibach, Oberscheld.	
7.	— biferus	Phil. pal. fos. 49. f. 230.	.....	...	*	...	...	Petherwin.	
8.	— bi-impressus	de B. Gon. u. Clym. in Schl. 1. f. 2.	.....	...	*	...	...	Ebersdorf.	
9.	— Bronnii	Münst. Beitr. H. 1. p. 22.....	.....	...	*	...	...	Gerlas, near Geroldsgrün.	
10.	— Buchii.....	nob. Tab. Nos. XXVI. 1 *a*, *b*. p. 1. var. 2 *a*, *antè*, p. 340.	.....	...	*	...	...	Brilon.	
11.	— Bucklandi	Münst. Beitr. H. 1. 18. f. 5. p. 28.....	.....	...	*	...	...	Schübelhammer.	
12.	— calculiformis	Beyr. 2. f. 5 *a–c*. p. 37. *antè*, p. 342.	.....	...	*	...	...	Oberscheld.	
13.	— carbonarius	Gold., Dech., de B. 2. f. 9; G. Listeri, Index Min. C. 501; A. subcrenatus, Schlot. 11. f. 9.	.....	...	...	...	*	Hoffnung, Werden, Yorkshire, C., Diluv. of Rhine and Ruhr.	
14.	— canalifer.....	Münst. Beitr. H. 1. 18. f. 2. p. 26	.....	...	*	...	...	Schübelhammer.	
15.	— cancellatus	nob. Tab. Nos. XXV. f. 6, 6 *b*. *antè*, p. 339.	.....	...	*	...	...	Brilon.	
16.	— ceratitoïdes	de B. Gon. u. Clym. in Schl. 1. f. 3. an G. serpentinus, Phil. Geol. York. Part ii. 20. f. 48–50?	.....	...	...	...	*	Falckenberg.	
17.	— carinatus	Beyr. 2. f. 2. p. 35.	.....	...	*	...	...	Oberscheld.	
18.	— clymeniformis ...	Münst. Beitr. H. 1. 17. f. 4.	.....	...	*	...	...	Gattendorf.	
19.	— compressus?	id. Abh. 1832. p. 33.....	.....	...	*	...	...	Elbersreuth.	
20.	— compressus	Beyr. 1. f. 6; Spirula compressa, Gold., Dech.; Gyroceratites gracilis, H. v. Meyer; id. Bronn, 1. f. 6. *antè*, p. 338.	*	...	...	...	...	Wissenbach.	
21.	— contiguus	Münst. Abh. 1832. 3. f. 8.	.....	...	*	...	...	Schübelhammer.	
22.	— id. var. *b*.	.....	.....	...	*	...	...	ib.	
23.	— Cottai.....	id. Beitr. H. 1. p. 25.	.....	...	*	...	...	ib.	
24.	— costulatus	nob. XXVI. f. 3 *a*, *b*. *antè*, p. 341.	.....	...	*	...	...	Brilon.	
25.	— costatus	nob. XXXI. f. 1 *a*. *antè*, p. 340.	.....	...	*	...	...	Eibach.	
26.	— cucullatus	de B. G. u. Clym. 1. f. 4.....	.....	...	*	...	...	Ebersdorf.	
27.	— divisus	Münst. Abh. 1832. 4. f. 6.	.....	...	*	...	...	Geigen, near Hof.	
28.	— Dannenbergii.....	Beyr. 1. f. 5. *antè*, p. 338.....	*	...	...	...	...	Wissenbach.	
29.	— æquabilis	id. 2. f. 1.	.....	...	*	...	...	Oberscheld.	
30.	— evexus.....	de B. Gon. 1. f. 3, 4, 5.	.....	...	*	...	...	Pelm, near Gerolstein.	
31.	— expansus.....	id. 1. f. 1, 2.	.....	...	*	...	*	Herborn, Derbyshire.	
32.	— falcifer	Münst. Beitr. H. 3. 16. f. 7.	.....	...	*	...	...	Schübelhammer.	
33.	— globosus.....	id. Abh. 1832. 4. f. 4. p. 20; Phil. pal. fos. 50. f. 231.	.....	...	*	...	...	Newton Bushel, Gattendorf.	
34.	— gracilis	id. ib. p. 33.....	.....	...	* ?	...	...	Schwarzenbach am Wald.	
35.	— Hœninghausi.....	de B. Gon. 2. f. 3; Bronn, f. 1. Tab. nob. XXV. f. 7 *a*, *b*. *antè*, p. 339.	.....	...	*	...	...	Eifel, Refrath.	

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36.	Goniatites Haueri ...	Münst. Beitr. H. 3. 16. f. 10.			*			Fichtelgebirge.	
37.	— hybridus	id. Abh. 1832. 3. f. 6. p. 19			*			Gerlas, near Geroldsgrün.	
38.	— incertus	nob. Tab. Nos. XXVI. f. 6 *a. antè*, p. 342			*			Brilon.	
39.	— insignis	Phil. pal. fos. 49. f. 228.			*			Petherwin.	
40.	— intermedius	Münst. Beitr. H. i. 18. f. 7			*			Schübelhammer.	
41.	— intumescens	Beyr. 2. f. 3.			*			Oberscheld.	
42.	— lateseptatus	id. 1. f. 1–4, *antè*, p. 338	*	*	*			Wissenbach, S., ib. D.	
43.	— latestriatus	nob. Tab. Nos. XXVI. f. 5 *a. antè*, p. 341			*			Eibach, Pessacher.	
44.	— linearis	Münst. Abh. 1832. 5. f. 1. p. 22; Phil. pal. fos. 49. f. 229.			*			Petherwin, Schübelhammer.	
45.	— maximus	Münst. Beitr. H. 1. 18. f. 8			*			Schübelhammer.	
46.	— multiseptatus	de B. Gon. 2. f. 6			*			Eifel?	
47.	— multilobatus	Beyr. 1. f. 9.			*			Oberscheld.	
48.	— Münsteri	de B. Gon. 2. f. 5; Münst. Beitr. H. 1. p. 22; Abh. 5. f. 3. p. 25.			*			Elbersreuth.	
49.	— Nœggerathi	id. 1. f. 6, 7, 8. Tab. Nos. XXV. f. 1 *a, b. antè*, p. 337.	*					Wissenbach.	
50.	— obscurus	Münst. H. 1. p. 31.			*			Elbersreuth.	
51.	— orbicularis	id. Abh. 1832. 5. f. 4. p. 26.			*			Schübelhammer.	
52.	— orbiculus	Beyr. 2. f. 4.			*			Eifel.	
53.	— ovatus	Münst. Abh. 1832. 4. f. 1. p. 4.			*			Gattendorf.	
54.	— pauciseptatus	Münst. H. 1. p. 31.			*			Elbersreuth.	
55.	— paucistriatus	nob. Tab. Nos. XXV. f. 8 *a, b. antè*, p. 339			*			Oberscheld, Adorf.	
56.	— pessoides	de B. Gon. u. Clym. in Schl. 1. f. 1.			*			Ebersdorf.	
57.	— Petræos	Münst. Beitr. H. 1. p. 18.			*			Gattendorf.	
58.	— planus	id. Abh. 1832. 6. f. 4. p. 30.			*			Schübelhammer.	
59.	— planidorsatus	id. Beitr. H. 1. 3. f. 7.			*			Gattendorf.	
60.	— Preslii	id. ib. 17. f. 3.			*			Schübelhammer.	
61.	— primordialis	Schlot. de B. Gon. 1. f. 15, 16, 17.			*			Gründt, Goslar.	
62.	— priscus	Gold.					*	Herborn.	
63.	— retrorsus	de B. Gon. 2. f. 13; Beyr. 1. f. 10; nob. Tab. Nos. XXV. f. 2 *a, b*, 3. *antè*, p. 338.			*			Oberscheld, Adorf, Martenberg.	
64.	— id. var. *a.*	nob. Tab. Nos. XXV. f. 4. *antè*, p. 338			*			ib.	
65.	— id. var. *b.*	nob. Tab. Nos. XXV. f. 5. *antè*, p. 338			*			ib.	
66.	— quadripartitus	Münst. Beitr. H. 1. p. 19.			*			Gattendorf.	
67.	— Roemeri	Münst. H. 1. 18. f. 3			*			Schübelhammer.	
68.	— serpentinus	Phil. Geol. York. 20. f. 48–50, id. pal. fos. 51. f. 237.			*	*		Newton, Devons., D., Yorks., Visé, C.	
69.	— simplex	de B. Gon. 2. f. 8. *antè*, p. 339.			*			Oberscheld, Rammelsberg, near Goslar.	
70.	— solaroïdes	id. Gon. und Clym. in Schl. 1. f. 5			*			Ebersdorf.	
71.	— sulcatus	Münst. Abh. 1832. 3. f. 7			*			Schübelhammer.	
72.	— speciosus	id. ib. 6. f. 1; Beitr. H. 1. 18. f. 6; de B. 2. f. 7.			*			ib.	
73.	— spirulæformis	id. H. 1. p. 31.			*			Elbersreuth.	
74.	— spurius	id. Abh. 1832. p. 31.			*			Schübelhammer.	
75.	— sphæricus	Mart. 7. f. 3, 4; Min. C. (Index) 53. f. 2. an id. striatus? id. A. Æthiope auct.					*	Herborn, Chokier, Visé, Derbys., Yorks., Isle of Man, Dil. of Rhine.	State of New York (Gon. minimus, Conr.).
76.	— striatus	Min. C. t. 53. f. 1; Phil. Geol. York. 19. f. 1–3, *antè*, p. 342.					*	ib. Bredlar, Derbys., Yorks.	
77.	— striatus	Münst. Beitr. H. 1. p. 20. no. 19. (non Sow.)			*			Schübelhammer.	
78.	— striatulus	id. Beitr. H. 1. p. 20. no. 20, H. 5. 12. f. 8.			*			Gattendorf.	
79.	— subarmatus	id. Abh. 1832. 6. f. 2. p. 28			*			Schübelhammer.	
80.	— subevexus	id. Beitr. H. 1. p. 18.			*			Naïla. 9 miles west of Hof.	
81.	— subglobosus	id. ib. p. 19.			*			Gattendorf.	
82.	— subbilobatus	id. ib. 17. f. 1.			*			ib.	
83.	— subinvolutus	id. ib. 17. f. 2.			*			ib.	
84.	— subcarinatus	id. ib. 18. f. 1.			*			Schübelhammer.	
85.	— sublinearis	id. Abh. 1832. 4. f. 5. p. 22			*			Gattendorf.	
86.	— sublævis	id. ib. 4. f. 2. p. 20.			*			ib.	
87.	— subnautilinus	Schlot., de B. Gon. 1. f. 9, 10, 11.	*					Wissenbach.	
88.	— subpartitus	Münst. Beitr. H. 1. p. 18			*			Gattendorf.	
89.	— subsulcatus	id. Abh. 1832. 5. f. 2. p. 23			*			Schübelhammer.	
90.	— tenuistriatus	nob. Tab. Nos. XXVI. f. 7 *a, b*, 8 *a*, *antè*, p. 343.			*			Brilon.	
91.	— transitorius	Phil. pal. fos. 60. f. 227*			*			Newton, Devons.	
92.	— tripartitus	Münst. Beitr. H. 1. p. 20. no. 17.			*			Schübelhammer.	
93.	— tuberculosus	nob. Tab. Nos. XXVI. f. 4 *a, b. antè*, p. 342.			*			Brilon.	
94.	— umbilicatus	Münst. Beitr. H. 1. p. 20. no. 18.			*			Gattendorf.	
95.	— undulosus	id. Abh. 1832. 4. f. 3. p. 20			*			ib.	

No. of Species.	Genera and Species.	Authors and References. The numerals refer to Species described and figured in this Memoir.	Sil. Sp. in Rhen. Prov.	Dev. & Sil. Sp.	Devonian Sp.	Dev. & Carb. Sp.	Carb. Sp.	Localities in Europe.	Elsewhere.
96.	Goniatites Ungeri ...	Münst. Beitr. H. 3. 16. f. 8			*			Schübelhammer.	
97.	— Verneuili ...	id. ib. H. 1. 3. f. 9			*			Gattendorf.	
98.	— (indeterm.)				*			Wetzlar.	
1.	Clymenia angulosa...	id. ib. H. 1. 16. f. 3.			*			Schübelhammer.	
2.	— angustiseptata ...	id. Abh. 1832. 1. f. 3			*			Fichtelgebirge.	
3.	— annulata	id. ib. 6. f. 6; Beitr. H. 1. p. 14			*			Schübelhammer.	
4.	— bilobata	id. H. 1. 2. f. 6.			*			ib.	
5.	— binodosa	id. ib. 2. f. 3.			*			Fichtelgebirge.	
6.	— id. var. *a.* nodosa.				*			ib.	
7.	— bisulcata	id. H. 3. 16. f. 6.			*			Schübelhammer.	
8.	— cincta	id. H. 1. 16. f. 5.			*			Fichtelgebirge.	
9.	— compressa	id. Abh. 1832. 1. f. 4.			*			ib.	
10.	— id. var. costata ...	id. ib.			*			ib.	
11.	— costulata	id. Beitr. H. 3. p. 94.			*			Schübelhammer, Gattendorf, Geiser, Gerlas.	
12.	— dorsocostata	id. ib. H. 3. 1840. 16. f. 5.			*			ib.	
13.	— Dunkeri	id. H. 1. 16. f. 1.			*			Gattendorf.	
14.	— fasciata	Phil. pal. fos. 53. f. 242.			*			Petherwin.	
15.	— flexuosa	Münst. Beitr. H. 3. 16. f. 4			*			Geiser.	
16.	— inæquistriata	id. Abh. 1832. 2. f. 4			*			Fichtelgebirge.	
17.	— id. var. elliptica...	id. ib. 1832. 2. f. 4. p. 10			*			ib.	
18.	— inflata	id. ib. 1. f. 5.			*			ib.	
19.	— lata	id. Beitr. H. 1. p. 7.			*			ib.	
20.	— lævigata	id. Abh. 1832. 1. f. 1; Planulites, id.; Phil. pal. fos. 52. f. 239.			*			Petherwin, Fichtelgebirge.	
21.	— id. var. *a.*, elliptica	id. Beitr. H. 3. p. 91.			*			Fichtelgebirge.	
22.	— id. var. *b.* semicingulata	id. ib.			*			ib.	
23.	—id.var.*c.*semiplicata	id. ib.			*			ib.	
24.	— id. var. *d.* nana ...	id. ib.			*			ib.	
25.	— id. var. *e.* speciosa	id. ib.			*			ib.	
26.	— linearis	id. Abh. 2. f. 5; Endosiphonites minutus, Ansted; Camb. Phil. Trans. vi. 8. f. 3; Phil. pal. fos. 53. f. 241.			*			Petherwin, Fichtelgebirge.	
27.	— ornata	id. Beitr. H. 1. 2. f. 7.			*			Fichtelgebirge.	
28.	— id. var. decorata ..	id. ib. H. 3. p. 91			*			ib.	
29.	— paradoxa	id. H. 1. 16. f. 6.			*			ib.	
30.	— planidorsata	id. Abh. 1832. p. 7.			*			Fichtelgebirge.	
31.	— planorbiformis	id. ib. 1. f. 1.			*			ib.	
32.	— pleurisepta	Phil. pal. fos. 54. f. 244.			*			Petherwin.	
33.	— plicata	Münst. H. 1. 16. f. 4.			*			Fichtelgebirge.	
34.	— pygmæa	id. Abh. 1832. 1. f. 2.			*			ib.	
35.	— sagittalis	Phil. pal. fos. 54. f. 243.			*			Petherwin.	
36.	— Sedgwicki	Münst. Beitr. H. 3. 16. f. 3.			*			Geiser.	
37.	— semicostata	id. H. 1. 16. f. 2.			*			Schübelhammer.	
38.	— semistriata	id. ib. p. 11, 8, 22			*			Fichtelgebirge.	
39.	— serpentina	id. Abh. 1832. 3. f. 1.			*			ib.	
40.	— similis	id. Beitr. H. 1. p. 11			*			ib.	
41.	— striata	id. Abh. 1832. 3. f. 2–5; Phil. pal. fos. 53. f. 240.			*			ib. Petherwin.	
42.	— id. var. *a.* costellata	id. ib. p. 13; Beitr. H. 1. p. 11.			*			ib.	
43.	— id. var. *b.* semistriata	id. ib. p. 14. ib. p. 11. l. 3. f. 4			*			ib.	
44.	— id. var. *c.* plana...	id. ib. 3. f. 2.			*			ib.	
45.	— id. var. *d.* umbilicata	id. ib.			*			ib.	
46.	— subflexuosa	id. Beitr. H. 3. p. 93.			*			Geiser.	
47.	— sublævis	id. Abh. 1832. 2. f. 3			*			Fichtelgebirge.	
48.	— subnodosa	id. ib. 6. f. 7. p. 32.			*			ib.	
49.	— tenuistriata	id. Beitr. H. 1. p. 11.			*			ib.	
50.	— undulata	id. Abh. 1832. 2. f. 2.			*			ib.	
51.	— valida	Phil. pal. fos. 54. f. 245.			*			Petherwin.	
1.	Orthoceratites acuarius	Münst. Beitr. H. 3. 17. f. 5.			*			Elbersreuth, Gattendorf.	
2.	— anceps?	id. ib. 9. f. 6.			*			Gattendorf.	
3.	— anguliferus	nob. Tab. Nos. XXVII. 6. *antè*, p. 346			*			Paffrath.	
4.	— articulatus	Sow. Sil. Syst. 5. f. 31. an Lit.? id. ib. 11. f. 5, 7.	*					Martelange.	

No. of Species.	Genera and Species.	Authors and References. The numerals refer to Species described and figured in this Memoir.	Sil. Sp. in Rhen. Prov.	Dev. & Sil. Sp.	Devonian Sp.	Dev. & Carb. Sp.	Carb. Sp.	Localities in Europe.	Elsewhere.
5.	Orthoceratites bullatus.	Sow. Sil. Syst. (O. striatum ? text) 5. f. 29, Min. C. 58.	...	*	*	...	...	Ludlow, S., Horeb Chapel, D.	
6.	— calamiteus	Münst. Beitr. H. 1. 17. f. 5. (O. cingulatus, Gold. Bonn Mus.) *antè*, p. 346.	*	*	*	...	...	Wissenbach, S., Chimay, Belgium, Refrath, Eifel, Brilon, Schübelhammer,	
7.	— carinatus	Münst. Beitr. H. 3. 19. f. 8	...	...	*	...	...	Elbersreuth. [D.	
8.	— cinctus	Min. C. 588. f. 3.; Münst. Beitr. H. 3. 19. f. 4; Phil. pal. fos. 41. f. 204; O. bacillus, Eichw. Zool. Sp. vol. ii. 2. f. 14. and Sil. Syst. in Esthl. p. 94; O. centralis, His. Suec. 9. f. 4.	...	*	*	*	...	Revel, Sweden, S.; Petherwin, Newton, Schübelhammer, D.; Lancash., Yorkshire, Visé, Tournay, C.	
9.	— conoideus	Münst. Beitr. H. 3. 18. f. 4, 5	...	...	*	...	...	Elbersreuth.	
10.	— costulatus	id. ib. 19. f. 7.	...	...	*	...	...	ib.	
11.	— cylindraceus	Sow. Geol. Trans. vol. v. 57. f. 28. and 52. f. 6, 7; Phil. pal. fos. 43. f. 213. (affinis O. cinctus.)	...	...	*	*	...	Newton, Baggy Point? D.—Venn, Swimbridge, &c., C.	
12.	— Dannenbergii	nob. Tab. Nos. XXVIII. 1 *a. antè*, p. 345	*	...	...	...	...	Wissenbach.	
13.	— decussatus	Münst. Beitr. H. 1. 13. f. 2.	...	...	*	...	...	Elbersreuth.	
14.	— dimidiatus	Sow. Sil. Syst. 8. f. 18; Münst. Beitr. H. 3. 19. f. 2, 5.	*	*	*	...	...	Wissenbach, Radnor Forest, S., Fichtelgebirge, D.	
15.	— duplicatus	Münst. Beitr. H. 3. 19. f. 10.	...	...	*	...	...	Elbersreuth.	
16.	— ellipsoideus	Phil. pal. fos. 60. f. 205*.	...	...	*	...	...	Newton.	
17.	— ellipticus	Münst. Beitr. H. 3. 18. f. 2.	...	...	*	...	...	Gattendorf.	
18.	— excepticus	Gold. Bonn Mus.	...	...	*	...	...	Bensberg.	
19.	— giganteus	Min. C. 246; Phil. Geol. Yorks. 21. f. 3; De la B. Geol. Man. Fr. Tr. p. 556.	...	...	*	*	*	Elbersreuth? Gerolstein, D.; Yorkshire, Closeburn, Scotland, C.	
20.	— gracilis	Blum., Arch. Tellur. 2. f. 6., nob. Tab. Nos. XXVII. 4. *antè*, p. 443.	*	...	...	...	...	Wissenbach.	
21.	— granulatus	Münst. Beitr. H. 3. 9. f. 4.	...	...	*	...	...	Elbersreuth, St. Sauveur.	
22.	— gregarius	Sow. Sil. Syst. 8. f. 16.; Münst. Beitr. H. 3. 18. f. 1. *b*.	...	*	*	...	...	Ludlow, S.; ib. ib., D.	
23.	— Ibex	Sow. ib. 5. f. 30; non Phil. pal. fos. 43. f. 208; O. annulatus, His. Leth. Suec. 9. f. 8. (non Min. C.) an O. articulatum? *antè*, p. 346.	*	*	*	...	...	Wissenbach, East Gottland, Ludlow, S., Petherwin, D.	
24.	— imbricatus	Wahl., His. 9. f. 9; Sow. Sil. Syst. 9. *f.* 2; Phil. pal. fos. 41. f. 207. (O. undulata, Min. C.? non Schlot.)	...	*	*?	*	...	Ludlow, Gottland, S., Marwood, D., Yorkshire, Visé, C.	
25.	— interruptus	Münst. Beitr. H. 3. 9. f. 3.	...	...	*	...	...	Gattendorf.	
26.	— irregularis	id. ib. 19. f. 11.	...	...	*	...	...	Elbersreuth, Prague.	
27.	— lateralis	Phil. Geol. Yorks. Part 2. 21. f. 8, Pal. fos. 41. f. 205.	...	...	*	*	...	Petherwin, Newton, D.; Yorkshire, C.	
28.	— linearis	Münst. Beitr. H. 3. 19. f. 1. *antè*, p. 345.	...	...	*	...	...	Elbersreuth, Oberscheld.	
29.	— lineolatus	Sow., Phil. pal. fos. 43. f. 209, *b*, O. annulatum id. Geol. Yorks. 21. 9, 10.	...	...	*?	*	...	Croyde Bay, Chimay, Belgium, D.; Visé? C.	
30.	— Ludensis	Sow. Sil. Syst. 9. f. 1; O. maximus, Münst. Beitr. H. 3. 17. f. 2.	...	*	*	...	...	Ludlow, Revel, S.; Petherwin, Marwood, Elbersreuth, D.	
31.	— nodulosus	Schlot. 11. f. 2. nob. Tab. Nos. XXXI. 4. *antè*, p. 347.	...	...	*	...	...	Eifel.	
32.	— punctatus?	Münst. Beitr. H. 3. 9. f. 5.	...	...	*	...	...	Elbersreuth.	
33.	— regularis	Schlot. 9. f. 3; id. Bronn; Münst. Beitr. H. 3. 17. f. 3, 4; His. O. recta, Bosc.; O. Œlandicus, Knorr., *antè*, p. 344.	*	*	*	...	...	Prague; Wissenbach, Oeland, St. Petersburg, Revel, West Gottland, S., Eifel, Elbersreuth, D.	
34.	— id. var.	nob. Tab. Nos. XXVII. 2. *antè*, p. 345.	*	...	...	...	...	Wissenbach.	
35.	— scalaris	Gold. Bonn Mus. *antè*, p. 345	...	...	...	...	*	Herborn.	
36.	— semipartitus	Sow. Sil. Syst. 3. f. 9.	...	...	*	...	...	Felindre, Horeb Chapel.	
37.	— semiplicatus	Münst. Beitr. H. 3. 18. f. 7.	...	...	*	...	...	Schübelhammer.	
38.	— speciosus	id. ib. f. 3.	...	...	*	...	...	Elbersreuth.	
39.	— striatulus	id. ib. 20. f. 5.	...	...	*	...	...	Schübelhammer.	
40.	— striatulus	Sow. Geol. Trans. vol. v. 54. f. 20; Phil. pal. fos. 43. f. 212.	...	...	*	...	...	Petherwin.	
41.	— striolatus	H. v. Mey., Nov. Act. Cur. vol. xv. 55. Tab. Nos. XXVII. 5, *a. antè*, p. 345.; O. fragilis, Schl. Collect. Jahr. für Min. 1833, p. 483.	...	...	...	...	*	Herborn.	
42.	— striatopunctatus	Münst. Beitr. H. 3. 20. f. 1	...	...	*	...	...	Elbersreuth.	
43.	— subannularis	id. ib. 19. f. 3	...	...	*	...	...	ib.	
44.	— subflexuosus	id. ib. 19. f. 9	...	...	*	...	...	ib.	
45.	— subfusiformis	id. ib. 20. f. 6, 7; Tab. Nos. XXVIII. 2, *a. antè*, p. 347.	...	...	*	...	...	Oberscheld, Pskof, Schübelhammer.	

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46.	Orthoceratites subpyriformis.	Münst. Beitr. H. 3. 20. f. 10; O. inflatus, Gold. Bonn M. Tab. Nos. XXVIII. 3, *a. antè*, p. 347.			*			Eifel, Paffrath, Schübelhammer.	
47.	— subtrochleatus	id. ib. 19. f. 6.			*			Elbersreuth.	
48.	— tentacularis	Phil. pal. fos. 43. f. 210.			*			Baggy Point, Brushford, Meadsfood Sands, Devonshire.	
49.	— tenuistriatus	Münst. Beitr. H. 3. 20. f. 4			*			Schübelhammer.	
50.	— torquatus	id. ib. p. 101.			*			Elbersreuth.	
51.	— triangularis	nob. Tab. Nos. XXVII. 1, *a. antè*, p. 347.	*					Wissenbach.	
52.	— tubicinellus	Sow. Geol. Trans. 57. f. 29; Phil. pal. fos. 43. f. 211, an calamiteus? Münst.			*			Newton, Plymouth, Chimay.	
53.	— venustus	Münst. Beitr. H. 3. 18. f. 6.			*			Elbersreuth.	
54.	— Wissenbachii	nob. Tab. Nos. XXVII. 3. *antè*, p. 345.	*					Wissenbach.	
55.	— id. var.		*					ib.	
56.	— siphon? d'orth.	Tab. Nos. XXX. 3, *a. antè*, p. 348.			*			Paffrath.	
1.	Cyrthoceratites angustiseptatus.	Münst. Beitr. H. 3. 17. f. 1.			*			Elbersreuth.	
2.	— arcuatus	Orth. id. Stein. 22. f. 6; Cyrth. rusticum, Phil. pal. fos. 46. f. 222.			*			Petherwin, Eifel.	
3.	— armatus	Phil. pal. fos. 48. f. 225; an Spirula tuberculata? Eichw. Jahr. für Min. 1840, p. 620.			*	*		Newton, Valdaï, Vitegra, D.; Yorkshire, C.	
4.	— Bdellalites	id. ib. 47. f. 223.			*			Torquay, Babbacombe.	
5.	— depressus	Gold., Bronn, Leth. Geogn. 1. f. 5; nob. Tab. Nos. XXIX. 1, *a. antè*, p. 350.			*			Paffrath, Eifel.	
6.	— id. var. carinata	nob.			*			ib.	
7.	— Eifelensis	nob. Tab. Nos. XXXI. 2, *a, b. antè*, p. 349.			*			Eifel.	
8.	— fimbriatus	Phil. ib. 44. f. 214.			*			Newton.	
9.	— flexuosus	Orth., id. Schlot. 8. f. 1.			*			Eifel.	
10.	— lamellosus	nob. Tab. Nos. XXVIII. 4, *a, b. antè*, p. 348.			*			Paffrath.	
11.	— lævis	Sow. Sil. Syst. 8. f. 21.		*	*			Ludlow, S.; Eifel, D.	
12.	— lineatus	Gold. (Bonn. M.) Tab. Nos. XXX. 2 *a. antè*, p. 351.			*			Eifel, Paffrath.	
13.	— marginalis	Phil. pal. fos. 46. f. 219. *a, b.*			*			Newton.	
14.	— nautiloïdes	Orth. id. Stein. 23. f. 1.			*			Eifel.	
15.	— nautiloïdeus	Phil. ib. 46. f. 220.			*			Newton.	
16.	— nodosus	Phil. ib. 46. f. 221; Spirula nodosa, Bronn, 1. f. 4; Lit. lituus, His. 8. f. 5; Ortolus convolvens, Montf., Stein. Mém. Soc. Géol. Fr. vol. i. 23. f. 3, *a.*		*	*			Dalecarlia, Oeland, S.; Plymouth, Newton, D.	
17.	— ornatus	Gold. (Bonn Mus.) Phil. ib. 45. f. 217. Tab. Nos. XXVIII. 5 *a, b. antè*, p. 349.			*			Newton, Eifel, Paffrath.	
18.	— obliquatus	Phil. ib. 45. f. 218.			*			ib.	
19.	— quindecimalis	id. ib. 44. f. 216.			*			ib.	
20.	— reticulatus	id. ib. 48. f. 224.			*			ib.	
21.	— tetragonus	nob. Tab. Nos. XXXI. 3, *a. antè*, p. 351.			*			Eifel.	
22.	— tredecimalis	Phil. ib. 44. f. 215.			*			Newton.	
23.	— ungulatus	Münst. Beitr. H. 1. 17. f. 6, an C. læve, Sow.			*			Elbersreuth.	
1.	Phragmoceratites Brateri.	id. H. 3. 1. f. 10			*			Gattendorf.	
2.	— subventricosus	nob. Cyrt. compressus, Gold. (Bonn Mus.) Tab. Nos. XXX. 1, *a. antè*, p. 351.			*			Eifel, Paffrath.	
1.	Nautilus divisus	Münst. Jahr. für Min. 1830. p. 485.					*	Herborn, Edderbringhausen.	
2.	— germanus	Phil. ib. 48. f. 226.			*			Newton.	
3.	— globatus	Min. C. 181; Phil. 17. f. 20–28; N. Wrightii, Flem. Brit. Anim. p. 230.					*	Ratingen.	
4.	— megasypho	Phil. pal. fos. 48. f. 227.			*			Petherwin.	
1.	Aptychus antiquus	Gold. (Bonn Mus.)					*	Herborn.	
2.	— vetustus	nob. Tab. Nos. XXVI. 9. *antè*, p. 343.			*			Eifel.	
	Heteropoda.								
1.	Bellerophon acutus	Sow. Sil. Syst. 19. f. 14.		*	*			Horderley, S., Elbersreuth, D.	South Africa.
2.	— apertus	Min. C. 469. f. 1. Phil. 17. f. 4.		*	*	*		Ledbury, S., Eifel, D., Coalbrook Dale, Yorkshire, Bristol, C.	State of New York, S.
3.	— Urii	Flem. Brit. Anim. p. 338; id. Phil. pal. fos. 40. f. 199; Atlantoïdes, d'Orb., Monog. des Céphalop. 4. f. 14–19.		*	*	*		Onny River, Longville, S., Pilton, Baggy Point, D., Yorkshire, Tournay, C.	
4.	— carinatus†	Sow. Sil. Syst. 3. f. 4.			*			Horeb Chapel, D.	

† Mr. Murchison has placed this fossil in the Upper Ludlow in his table, but he does not give any locality.

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5.	Bellerophon Cornu Arietis.	Min. C. 469. f. 2, 3; Phil. Geol. York, 17. f. 16.	*	...	...	...	...	Kemmenau, Podolsk, Stolobinskoï, S; Kendal, C.; Northumberland, C.	
6.	— cultratus	d'Orb. Mon. des Céph. 7. f. 21–23	...	...	*	...	...	Eifel.	
7.	— Edouardii	d'Orb. ib. 7. f. 6, 7.	...	...	*	...	...	Eifel?	
8.	— elegans	d'Orb. 7. f. 15–18; B. decussatus? Flem. Brit. Anim. p. 338; Phil. 17. f. 13; Tab. Nos. XXIX. 2 *a, b. antè*, p. 354.	...	...	*	*	...	Paffrath, D; Kulkeagh, Linlithgowshire, Tournay, Visé, C.	
9.	— globatus	Sow. Sil. Syst. 3. f. 15, 4. f. 50; id? Phil. pal. fos. 40. f. 202.	*	*	*	...	...	Prussino, Ludlow, S., Marienheide, D; Felindre, Marwood.	
10.	— Goldfussii	d'Orb. loc. cit. supra. 5. f. 28–31	...	...	*	...	...	Eifel.	
11.	— hiulcus	Min. C. 470. f. 1; Phil. pal. fos. 58. f. 203*.	...	...	*?	*	...	Yealm Bridge, Ireland, Coalbrook Dale, Tournay, &c., C.	Tennessee.
12.	— Hupschii	Defr. Ann. Sc. Nat. 1824	...	...	*	...	...	Chimay, Blankenburg? (Hœn.)	
13.	— Murchisoni	d'Orb. 7. f. 1, 2, 3. (B. striatus, Sil. Syst. 3. f. 12, *e.*) XXVIII. 7 *a, b. antè*, p. 353.	*	*	*	...	...	Wissenbach, S., Felindre, D.	
14.	— id. var. *a.*	nob. Tab. Nos. XXVIII. 8. *antè*, p. 353	*	...	...	...	..	Wissenbach.	
15.	— radiatus	d'Orb., Porcell. retrorsus, Münst. Beitr. H. 1. 2. f. 8.	...	...	*	...	...	Eifel, Fichtelgebirge.	Ural & Altaï.
16.	— striatus	de Fer. and d'Orb. 7. f. 6, 7. (non Sow. Sil. Syst., non Bronn, non Phil. pal. fos.) B. undulatus, Gold. Bonn Mus., Tab. nos. XXVIII. 6. *antè*, p. 353.	...	...	*	...	...	Paffrath, Bellignies.	
17.	— striatus	Gold., Dech., Bronn, 1. f. 11; Phil. pal. fos. 40. f. 198.	...	...	*	...	...	Newton, Plymouth, Bensberg?	
18.	— subcarinatus	Münst. Beitr. H. 3. 16. f. 2.	...	...	*	...	...	Elbersreuth.	
19.	— trilobatus	Sow. Sil. Syst. 3. f. 16.	*	*	*	...	...	Shropshire, S; Felindre, Baggy Point, D.	
20.	— id. var. *b, c.*	Phil. pal. fos. 40. f. 200.	...	...	*	...	...	Torquay, Daun, Petherwin.	
21.	— tuberculatus	de Fer. and d'Orb. 8. f. 7–10; B. nodulosus, Gold. (Bonn Mus.) Tab. Nos. XXVIII. 9. *antè*, p. 353.	...	...	*	...	...	Eifel, Paffrath, Goslar.	
22.	— Volkofensis	nob. (ined.)	...	...	*	...	...	Tchudovo, Prussino near the Volkof.	
23.	— Wenlockensis	Sow. Sil. Syst. 13. f. 21; id.? Phil. pal. fos. 40. f. 203.	...	*	*	...	...	Wenlock, S., Newton, D.	
24.	— Woodwardii	Naut. id. Mart.; Petrif. Derb. 35. f. 4, 5. B. id. Min. C. (Index) 571; Phil. Geol. Yorks. Part 2. 17. f. 1, 2, 3; id. Pal. fos. 40. f. 201.	...	...	*	*	...	Newton, D.; Yorkshire, Derbyshire, Ireland, Tournay, Visé, C.	
1.	Porcellia cincta	Münst. Beitr. H. 3. p. 84	...	...	*	...	...	Elbersreuth.	
2.	— parvula	id. ib. ib.	...	...	*	...	...	ib.	
	Pteropoda.								
1.	Conularia Brongniarti	nob. Tab. Nos. XXXI. 6, *a, b, c. antè*, p. 353.	...	...	*	...	...	Néhou (La Manche).	
2.	— Gervillei	nob. Tab. Nos. XXIX. 3, 4. *antè*, p. 351.	*	*	*	...	...	Kemmenau, S., Néhou, D.	
3.	— Gerolsteinensis	nob. Tab. Nos. XXXI. 5, *a, b. antè*, p. 352.	...	...	*	...	...	Eifel.	
4.	— ornata	nob. Tab. Nos. XXIX. 5, *a. antè*, p. 352.	...	...	*	...	...	ib. Refrath.	
	Gasteropoda.								
1.	Rostellaria angulata	Phil. Geol. Yorks., Part 2. 16. f. 16.	...	...	...	...	*	Silesia, Bolland, Valdaï.	
2.	—? (ind.)	nob.	*	...	...	...	...	Prüm.	
1.	Buccinum acutum	Min. C. 566. f. 1; Sow. Geol. Trans. vol. v. 57. f. 23; Macrocheilus, Phil. (pal. fos. p. 104) has not adopted the reference with the shells of the carb. limest.	...	...	*	*	...	Plymouth, D; Whitewell, Bolland, Northumberland, Kildare, Ireland, Visé, C.	
2.	— arculatum	Buccinites id. Schlot. xiii. f. 1; Tab. Nos. XXXII. 1. *antè*, p. 354.	...	...	*	...	...	Paffrath.	
3.	— breve	Min. C. 566. f. 3; Macrocheilus? id. Phil. pal. fos. 39. f. 193.	...	...	*	...	...	Plymouth, Newton, Bradley.	
4.	— id. var.	nob. *antè*, p. 355.	...	...	*	...	...	Paffrath.	
5.	— imbricatum	Min. C. 566. f. 2; Sow. Geol. Trans. vol. v. 57. f. 23, *a*; Phil. Geol. Yorks. Part 2. 16. f. 9, 17, 20; Macrocheilus id.? Pal. fos. 39. f. 194.	...	...	*	*	...	Plymouth, Bradley, Newton, D.; Isle of Man, Yorkshire, C.	
6.	— Schlotheimii	nob. Bucc. subcostatus, Schlot. 12. f. 3; Macrocheilus arculatus, Phil. pal. fos. 60. f. 194*; Tab. Nos. XXXII. 2. *antè*, p. 354	...	...	*	...	...	Newton, Paffrath.	
1.	Macrocheilus elongatus.	Phil. pal. fos. 39. f. 195.	...	...	*	...	...	ib.	
2.	— neglectus	id. ib. f. 196.	...	...	*	...	...	Brushford.	

No. of Species.	Genera and Species.	Authors and References. The numerals refer to Species described and figured in this Memoir.	Sil. Sp. in Rhen. Prov.	Dev. & Sil. Sp.	Devonian Sp.	Dev. & Carb. Sp.	Carb. Sp.	Localities in Europe.	Elsewhere.
1.	Murex harpula	Min. C. 578. f. 5; Macrocheilus? id. Phil. pal. fos. 39. f. 197.			*			Plymouth, Bradley, Newton.	
1.	Loxonema Hennahiana.	Phil. pal. fos. 38. f. 184; Terebra id. Sow. Geol. Trans. vol. v. 57. f. 22.			*			ib.	
2.	— lincta	Phil. pal. fos. 38. f. 185.			*			Barton.	
3.	— nexilis	id. ib. f. 183; Tereb. id. Sow. Geol. Trans. vol. v. 54. f. 17; Mel. arcuata, Münst. Beitr. iii. 15. f. 2.			*			Newton, Petherwin, Schübelhammer.	
4.	— præterita	Phil. pal. fos. 38. f. 187. *a, b, c.*			*			ib. Plymouth, Chudleigh.	
5.	— sinuosa	Phil. pal. fos. 38. f. 182; Tereb.? id. Sow. Sil. Syst. 8. f. 15.		*	*			Aymestry, S., Petherwin, D.	
6.	— reticulata	id. ib. 60. f. 187*.			*			Newton.	
7.	— rugifera	id. ib. 38. f. 188; Mel. id. Geol. Yorks. 16. f. 26.			*	*		ib. Brushford, D.; Lake Ilmen, Otterburn, Northumb., Valdaï, Vitegra, C.	
8.	— tumida	id. ib. f. 186; Mel. id., Geol. Yorks. Part 2. 16. f. 2.			*	*		Petherwin, D.; Bolland, Ireland, Falckenberg, C.	
1.	Murchisonia angulata	id. ib. 39. f. 189; Rostellaria id. ib. 16. f. 16. Tab. Nos. XXXII. 6. *antè*, p. 356.			*	*		ib. Brushford, Paffrath, D.; Bolland, Visé, C.	
2.	— id. var. *a.*	nob. Tab. Nos. XXXII. 7. *antè*, p. 356.			*			Paffrath, &c.	
3.	— bigranulosa	nob. Tab. Nos. XXXII. 9. *antè*, p. 357.			*			ib.	
4.	— id. var. *a.*	nob. Turritella abbreviata, Min. C. 565. f. 2; Murch. bilineata? Phil. pal. fos. 39. f. 191. Tab. Nos. XXXII. 10. *antè*, p. 358.			*			ib. Bradley.	
5.	— id. var. *b.*	nob. Tab. Nos. XXXII. 11.			*			ib.	
6.	— bilineata	nob. Turrit. and Melan. id. Gold. Bonn Mus., non Phil. pal. foss.; Tab. Nos. XXXII. 8. *antè*, p. 356.			*			ib. Néhou, Izé, Weipperfeldt, 19 miles East of Cologne, &c.	
7.	— id. var. *a.*	nob.			*			ib.	
8.	— binodosa	nob. Tab. Nos. XXXII. 12. *antè*, p. 357.			*			Lustheide.	
9.	— coronata	nob. Turrit. id. and spinosa, Gold. Bonn Mus.; Beyrich, Verst. Rhein. Uberg. p.8.; Cerith. antiquum, Stein., Mém. Soc. Géol. France, tome i. p. 367. Tab. Nos. XXXII. 3. *antè*, p. 355.			*			Paffrath, Weipperfeldt, München-Mühle, &c.	
10.	— id. var. *a.*	nob.			*			ib.	
11.	— geminata	Phil. pal. fos. 39. f. 190.			*			Newton.	
12.	— intermedia	nob. Tab. Nos. XXXII. 4. *antè*, p. 356.			*			Paffrath.	
13.	— id. var. *a.*	nob. Tab. Nos. XXXII. 5. *antè*, p. 356.			*			ib.	
14.	— intermedia, var. *b.*	nob. *antè*, p. 356.			*			Paffrath.	
15.	— spinosa	Phil. pal. fos. 39. f. 192; Buccinum, Min. C. 566. f. 4; id. Sow. Geol. Trans. vol. v. 57. f. 24–27.			*	*		Plymouth, Bradley, D.; Whitewell, C. [C.	
16.	— tæniata	nob. Turrit. id. Phil. Geol. Yorks. Part 2. 16. f. 7. *antè*, p. 358.			*	*		Gronau, Paffrath, D.; Yorkshire, Visé,	
17.	— tricincta	nob. Phil. pal. fos. 60. f. 190*; Schizostoma id. Münst. Beitr. H. 3. 15. f. 14.			*			Newton, Elbersreuth.	
18.	— id. var. *a.*	nob. Tab. Nos. XXXII. 13 *a. antè*, p. 358.			*			Villmar.	
19.	— id. var. *b.*	nob.			*			Ferques.	
1.	Turritella acus (Sarcata).	de B. Gon. u. Clym. in Schl. f. 16. p. 18.					*	Falckenberg.	
2.	— antiqua	Münst. Beitr. H. 3. 15. f. 18.			*			Elbersreuth.	
3.	— compressa	id. ib. f. 19.			*			ib.	
4.	— conica	Sow. Sil. Syst. 3. f. 7, 8.			*			Horeb Chapel.	
5.	— gregaria	id. ib. 3. f. 1.			*			ib.	
6.	— lineata	Münst. Beitr. H. 3. 15. f. 21.			*			Elbersreuth.	
7.	— obsoleta	Sow. Sil. Syst. 3. f. 7–12			*			Horeb Chapel.	
8.	— tenuicarinata	Münst. Beitr. H. 3. 15. f. 20.			*			Elbersreuth.	
9.	— trochleata	id. ib. f. 17.			*			ib.	
10.	— (indeter.)	*antè*, p. 358.	*					Wissenbach.	
1.	Scholiostoma Dannenbergi.	Braun. Jahrb. für Min. 1838, p. 397.			*			Villmar.	
1.	Turbo bicarinatus	Wahl., His. Leth. Suec. 12. f. 3.; Buch. Gon. u. Clym. in Schl., p. 18.					*	East Gottland, Dalecarlia, S.; Falckenberg, C.	
2.	— carinatus	Sow. Sil. Syst. 5. f. 28.		*	*?			Ludlow Promontory, S., Oberscheld,	
3.	— cirriformis	Sow. Geol. Trans. vol. v. 57. f. 19, 20.			*			Plymouth. [D.	
4.	— cirrhosus	id. Sil. Syst. 13. f. 22.		*	*			Wenlock, S.; Eifel, D.	
5.	— helicinæformis?	Hœn., De la Beche, Man. Fr. edit.					*	Ratingen.	

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6.	Turbo inflatus	Münst. Beitr. H. 3. 15. f. 25.			*			Schübelhammer.	
7.	— Nerei	id. ib. f. 23.			*			Elbersreuth (Orth. lim.).	
8.	— ovatus	id. ib. f. 24.			*			ib.	
9.	— squamiferus	nob. Tab. Nos. XXXII. 14 *a. antè*, p. 358			*			Limburg.	
10.	— striatus	His. Leth. Suec. 12. f. 5.		*	*			Gottland, S., Paffrath, D.	
11.	— subangulatus	Sow. Geol. Trans. vol. v. 57. f. 18.			*			Plymouth.	
12.	— textatus	Münst. Beitr. H. 3. 15. f. 22; Phil. pal. fos. 37. f. 175.			*			Newton, Elbersreuth.	
13.	— Willamsii	Sow. Sil. Syst. 3. f. 6.			*			Horeb Chapel.	
1.	Monodonta purpurea	nob. Tab. Nos. XXXII. 15 *a. antè*, p. 358			*			Paffrath.	
1.	Trochus Bouei	Stein. 23. f. 4.			*			Newton, Eifel, Paffrath.	
2.	— catenulatus?	Hœn., De la Beche, Man. Fr. edit.					*	Ratingen.	
3.	— helicites	Sow. Sil. Syst. 3. f. 1–5.	*	*	*			Ludlow, Daun, S., Horeb Chapel, D.	
4.	— Ivanii, var.	nob. Lev. Mém. Soc. Géol. France, t. 1, 2. f. 24. Tab. Nos. XXXII. 16. *antè*, p. 359.			*	*		Villmar, D., Tournay, C.	
5.	— Neptuni	Münst. Beitr. H. 3. 15. f. 15.			*			Schübelhammer, Gattendorf.	
6.	— Petræos	id. ib. f. 16.			*			ib. ib.	
1.	Pleurotomaria aspera	Sow. Geol. Trans. vol. v. 54. f. 16.			*			Petherwin, Barnstaple, Newton.	
2.	— Beaumontii	nob. Tab. Nos. XXXIII. 1 *a. antè*, p. 361			*			Villmar.	
3.	— cancellata	Phil. pal. fos. 37. f. 176.			*			Petherwin, Pilton, Newton.	
4.	— catenulata	nob. Tab. Nos. XXXII. 17 *a. antè*, p. 360			*			Villmar.	
5.	— cirriformis	Sow. Min. C. (Index) 171. f. 2. an P. delphinuloïdes variety?			*			Plymouth, Paffrath?	
6.	— Defrancii	nob. Tab. Nos. XXXII. 22 *a. antè*, p. 360			*	*		Villmar, D., Visé, C.	
7.	— delphinuloïdes	Gold. (Bonn Mus.), Dech., Euomphalus id. Goldf., von Dechen's Handb. p. 532; Helicites id. Schlot. 11. f. 4. Tab. Nos. XXXIII. 4. *antè*, p. 361.			*	*		Paffrath, D.; Ratingen, Tournay, C.	State of New York.
8.	— id. var.	nob. Tab. Nos. XXXIII. 4 *a*.			*			ib.	
9.	— deperdita	de Koninck. (ined.)			*			Chimay.	
10.	— elegans	nob. Tab. Nos. XXXIII. 3 *a, b, c. antè*, p. 360.			*			Villmar.	
11.	— exaltata	nob. Tab. Nos. XXXIII. 5. *antè*, p. 361			*			Refrath.	
12.	— expansa	Phil. Geol. Yorks. 15. f. 4; id. Pal. 37. f. 179.			*	*		Baggy Point, D., Bolland, C.	
13.	— gracilis	id. Pal. fos. 37. f. 181.			*			ib. Brushford.	
14.	— impendens	Sow. Geol. Trans. 57. f. 16; Phil. pal. fos. 37. f. 180.			*			Plymouth, Newton, Hope.	
15.	— limbata, var.	Phil. Geol. Yorks. 15. f. 18. Tab. Nos. XXXIII. 2. *antè*, p. 361.			*	*		Paffrath, D.; Bolland, Visé, C.	
16.	— Lonsdalii	nob. Tab. Nos. XXXII. 21 *a. antè*, p. 359			*			Villmar.	
17.	— monilifera	Phil. Geol. Yorks. 15. f. 10 *a*, id. Pal. 37. f. 178.			*	*		Newton, D.; Bolland, Visé, C.	
18.	— Orbignyana	nob. Tab. Nos. XXXII. 18 *a. antè*, p. 359			*			Villmar.	
19.	20. id. var. *a, b.*	nob. Tab. Nos. XXXII. 19 *a*.			*			ib.	
21.	— undulata	Phil. Geol. Yorks. 15. f. 14. *antè*, p. 360.	*				*	Wissenbach, S., Bolland, C.	
22.	— (ind.)				*			Paffrath.	
1.	Cirrus Leonhardii	nob. Tab. Nos. XXXIV. 9, 9 *a. antè*, p. 365.			*			ib.	
2.	— rotundatus	Min. C. 429. f. 1, 2; Euomph. Dionysii, Gold., Dech. Handb. p. 532; id. Bronn, 2. f. 3; Helicites trochilinus, ellipticus, Schlot. 10. f. 2, 3; Pleurotomarium helicoides, Fisch. Oryct. Govern. Moscou, p. 129.					*	Ratingen, Yorkshire, Northumberland, Namur, Sablé, Stolobinskoï, Valdaï, Moscow.	
3.	— id. variety				*			Paffrath.	
1.	Euomphalus annulatus.	Phil. pal. fos. 60. f. 172*. Tab. Nos. XXXIII. 11 *a. antè*, p. 363.			*			ib. Newton.	
2.	— catillus	Mart. Min. C. 45. f. 3, 4; Phil. Geol. Yorks. 13. f. 1, 2; Schizostoma id. Bronn, 3. f. 10.					*	Falckenberg, Derbyshire, Buxton, Yorkshire, Visé, &c.	Lake Erie, State of New York.
3.	— circularis	Phil. pal. fos. 36. f. 171.			*			Newton.	
4.	— Goldfussi	nob. Tab. Nos. XXXIV. 1, 1*a*, 2, 2*a. antè*, p. 362.			*			Lustheide, Paffrath.	
5.	— granulatus	Münst. Beitr. H. 3. 15. f. 10.			*			Elbersreuth, Gattendorf, Schübelhammer, &c.	
6.	— heliciformis	Münst. ib. 15. f. 6.			*			Elbersreuth.	
7.	— helicinus	id. ib. f. 7.			*			ib.	
8.	— Labadyei	nob. Tab. Nos. XXXIII. 6 *a, b. antè*, p. 362.			*	*		Paffrath, D., Tournay, C.	
9.	— lævis	Gold. Helicites priscus? Schlot. 10. f. 1; Tab. Nos. XXXIII. 8 *a. antè*, p. 364.			*			Paffrath.	
10.	— pentangulatus	Min. C. 45. f. 1, 2; Phil. Geol. York. Part 2. 13. f. 13.					*	Ratingen; Yorkshire, Northumb., Dublin; Tournay, Namur, Visé, Sablé, Dwina, Fedotova, Miatchkova.	

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11.	Euomphalus planorbis	nob. Tab. Nos. XXXIII. 7 *a. antè*, p. 363.			*			Paffrath, Villmar.	
12.	— qualteriatus	Schlot. 11. f. 3; Gold., Bronn, 2. f. 1. *antè*, p. 363.		*	*			Gottland, Oeland, Dalecarlia, Christiania, Revel, &c., S.; Chimay, Paffrath, D.	
13.	— id. variety	nob.			*			Refrath.	
14.	— Schnurii	nob. Tab. Nos. XXXIV. 7, 7 *a*, 7 *b. antè*, p. 364.			*			Eifel.	
15.	— serpens	Phil. pal. fos. 36. f. 172.			*			Petherwin, Brushford, Newton, &c.	
16.	— serpula	de Kon. (ined.) Tab. Nos. XXXIII. 9 *a*, *b*. p. 363.			*	*		Paffrath, D., Belgium, Ireland, C.	
17.	— spiralis	Münst. Beitr. H. 3. 15. f. 8.			*			Elbersreuth (Orth. lim.).	
18.	— striatus	id. ib. f. 9.			*			ib.	
19.	— subcarinatus	id. ib. f. 5.			*			ib.	
20.	— trigonalis	Gold. (Bonn Mus.) nob. Tab. Nos. XXXIII. 10 *a*. p. 365; Spirorbis maximus, Stein. 22. f. 1; Solarium petropolitanum. Pander, 1. f. 28. f. 3. 14. p. 150. *antè*, p. 364.		*	*			St. Petersburg, S., Paffrath, D.	
1.	Schizostoma contraria	Münst. Beitr. H. 3. 15. f. 13.			*			Schübelhammer (Clym. lim.).	
2.	— bistriata	id. ib. f. 11.			*			Elbersreuth (Orth. lim.).	
3.	— antitorquata	id. ib. f. 12; Phil. pal. fos. 37. f. 176 *d*.			*			Schübelhammer, Petherwin, Newton.	
4.	— Puzosii	nob. Tab. Nos. XXXIV. 8, 8 *a*, 8 *b. antè*, p. 365.			*			Eifel.	
5.	— radiata	nob. Euomphalus radiatus, Gold. (Bonn Mus.) Phil. pal. fos. 60. f. 171*; Tab. Nos. XXXIV. 3, 3 *a*, 3 *b. antè*, p. 364.			*			ib. Newton.	
1.	Rotella helicinæformis.	Gold., v. Dechen's Handb. p. 533; Helic. id. Schlot. 11. f. 6.			*			Paffrath.	
1.	Scalaria antiqua	Münst. Beitr. H. 1. 13. f. 1.			*			Elbersreuth.	
1.	Nerita deformis	Sow. Geol. Trans. vol. v. 57. f. 14.			*			Plymouth.	
2.	— semistriata	Münst. Beitr. H. 3. 15. f. 3.			*			Schübelhammer (Clym. lim.).	
3.	— speciosa	Sow. Geol. Trans. vol. v. 57. f. 15.			*			Plymouth.	
4.	— venusta	Münst. Beitr. H. 3. 15. f. 4.			*			Elbersreuth (Orth. lim.).	
5.	— glaucinoïdes	Sow. Sil. Syst. 3. f. 14.			*			Felindre.	
1.	Natica margaritifera.	nob. Tab. Nos. XXXIV. 4, 4 *a. antè*, p. 366.			*			Paffrath.	
2.	— meridionalis	Phil. pal. fos. 36. f. 173.			*			Baggy Point.	
3.	— subcostata	nob. Nerita id. Gold. loc. cit. suprà, p. 532. Tab. Nos. XXXIV. 5, 5 *a. antè*, p. 366.			*			Paffrath.	
4.	— id. var. globosa	nob. N. nexicosta, Phil. pal. fos. 36. f. 174; Tab. Nos. XXXIV. 6.			*			Paffrath, Petherwin.	
5.	— (indeter.)		*					Ems.	
1.	Melania prisca	Münst. Beitr. H. 3. 15. f. 1.			*			Elbersreuth (Orth. lim.).	
2.	— striatula?	id. (an Loxonema Hennahii, 38. f. 184. Phil.)			*			ib.	
1.	Pileopsis cassideus	nob. Tab. Nos. XXXIV. 10, 10 *a. antè*, p. 366.	*					Kemmenau.	
2.	— priscus	Gold, von Dechen's Handb. p. 531; de Kon. (ined.)			*			Couvin, Huy.	
3.	— vetustus	Min. C. 607. f. 1, 2, 3; Phil. Geol. Yorks. 14. f. 19; Acroculia, id. Pal. fos. 36. f. 169; Capulus canalifer, Münst. Beitr. H. 3. 14. f. 27.			*	*		Plymouth, Newton, Eifel, Schübelhammer, D; Yorkshire, Whitewell; Tournay, C.	State of New York.
1.	Acroculia sigmoïdalis	Phil. pal. fos. 36. f. 170.			*			Torquay.	
1.	Parmophorus?	Beyr. Verst. Rhein., &c., p. 14.	*					Wissenbach.	
1.	Capulus trochleatus	Münst. Beitr. H. 3. 14. f. 28.			*			Schübelhammer.	
2.	— substriatus	id. ib. f. 29.			*			ib.	
1.	Patella antiqua	Schlot. Patellites antiquus, p. 113.					*	Ratingen.	
2.	— disciformis	Münst. Beitr. H. 3. 14. f. 23.			*			Elbersreuth.	
3.	— elliptica	id. ib. f. 25.			*			ib.	
4.	— lævigata	id. ib. f. 26.			*			ib.	
5.	— subradiata	id. ib. f. 24.			*			ib.	
6.	— speciosa	id. ib. p. 81.			*			Schübelhammer (Clym. lim.).	
7.	— Neptuni	Gold. (Bonn Mus.)	*					Wissenbach.	
1.	Dentalium striatum	Hœn. (ined.)			*			Eifel.	
2.	— ind.	(ined.)			*			Paffrath.	
	Brachiopoda.								
1.	Calceola sandalina	Lam.; Anom. Sandalium, Lin. and Gmel. (Crepite, Crepidolite, Sandalites, &c., de Hüpsch, Obser. Phy. t. iii. p. 150. 1.; Schröt.) Schlot. Petref. p. 173; Bronn, Leth. Geog. 3. f. 5; Phil. pal. fos. 60. f. 102*.			*			Chircombe Bridge, near Newton; Chimay, Couvin, Eifel, Brilon, Langenberg, Martenberg, Meschede, Goslar, Néhou, &c.	Perry county, States of Tennessee and Ohio.

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1.	Orbicula plana	Münst. Beitr. H. 3. 14. f. 22.			*			Schübelhammer (Clym. lim.).	
2.	— lævigata	id. ib. f. 21.			*			Elbersreuth (Orth. lim.).	
3.	— subrugata	id. ib. f. 20.			*			ib.	
4.	— (indeterm.)		*					Kemmenau, Le Faou (Finisterre).	
1.	Lingula cornea	Sow. Sil. Syst. 3. f. 3.			*			Tin Mill, Dorpat.	
2.	— ind.	(aff. cornea.)			*			Lethmate.	
1.	Crania obsoleta	Gold. Petref. 163. f. 9.			*			Eifel.	
2.	— proavia	id. ib. f. 10.			*			ib.	
1.	Terebratula acuminata.	Anom. Mart. Pet. Derb. 32. 33. Min. C. 324. f. 1; Phil. Geol. Yorks. 12. f. 4; id. Pal. fos. 35. f. 159.			*	*		Barnstaple, Plymouth, Newton, Eifel, D.; Cork, Yorkshire, Queen's County, Whitewell, Tournay, Visé, Sablé, C.	
2.	— ambligona	Phil. pal. fos. 35. f. 160.			*			Barton, Babbacombe.	
3.	— amygdalina	Bonn Mus. an Ter. caïqua?	*	*	*			Ems, Kemmenau, Niederosbach, S., Eifel, D.	
4.	— anceps	de Kon. (ined.)			*			Couvin.	
5.	— angularis	Phil. pal. fos. 35. f. 162.			*			Barton; Eifel.	
6.	— anisodonta	id. ib. 34. f. 154. aff. Ter. pleurodon			*			ib.	
7.	— aspera	Schlot. 18. f. 3. (an prisca, var.?); Atrypa Dalm., His. Leth. Suec. 21. f. 12; Phil. pal. fos. 33. f. 144. *a–d.* (non Atr. asp. Sow.) Atrypa squamosa, Sow. Geol. Trans. vol. v. 57. f. 2.	*	*	*			Gottland, Banks of the Langenaubach, Aggerthal, S., Plymouth, Newton, Torquay, Eifel, Paffrath, Refrath, Hagen, Voroneje, Rhisne, D.	Pennsylvania.
8.	— bifera	Phil. pal. fos. 34. f. 151. aff. At. latissima, Sow. Geol. Trans. vol. v. 56. f. 25.			*			Torquay.	
9.	— borealis	Schl., de B. Mém. Soc. Géol. Fr. t. iii. p. 117; Atrypa id. Conrad States' Report, New York, 1840, p. 202; T. lacunosa, Schl. Nachtr. 20. f. 6; Sow. Sil. Syst. 5. f. 19; non His. 23. f. 3. (affin. T. plicatella, Dalm., His. (non Sow. Min. Con.) T. crispata, Sow. Sil. Syst.; T. Stricklandii, id. ib.)	*	*	*			Ludlow, mouth of the Lahn, Braubach, S.; Refrath, Eifel, Newton, Ogwell, Plymouth, D.	State of New York.
10.	— Buchii	Münst. Beitr. H. 3. 14. f. 2.			*			Elbersreuth (Clym. lim.).	
11.	— caïqua	nob. Tab. Nos. XXXV. 1 *a, b. antè*, p. 367.			*			Paffrath.	
12.	— camelina	de Buch Beitr. Gebirgs Russland, p. 115; (T. impressa, Eichw.)			*?				Ural.
13.	— Cassidea	Atrypa, de B. Mém. Soc. Géol. France, t. 3. 19. f. 12; id. Dalm. Vet. Acad. Handl. 1827, 5. f. 5; id. His. Leth. Suec. 22. f. 6; Phil. pal. fos. 34. f. 148; (non Ter. Cassidea, Bronn.)		*	*			Wenlock, Ludlow, East Gottland, S.; Newton, Ogwell, Couvin, Eifel, Refrath.	New York.
14.	— cingulata	Münst. Beitr. H. 1. 14. f. 12, 13.			*			Elbersreuth (Orth. lim.).	
15.	— concentrica	de Buch; loc. cit. suprà, p. 214; Murch. Bul. de la Soc. Géol. de France, t. xi. 2. f. 1 *a, b, c*, p. 251. an Atrypa id. Conrad. *antè*, p. 366.			*			Newton, Torquay, Ferques, Chimay, Couvin, Huy, Néhou, Eifel, Refrath, Hübigenstein, Tchudovo.	State of New York? Serebrianka (Ural).
16.	— comta	Phil. pal. fos. 35. f. 161.			*			Barton.	
17.	— crumena	Min. 6. 83. f. 2, 3, quoted by Dannenberg			*?	*		Heigerselbach? D.; Derbyshire, Visé, C.	
18.	— crispata	Sow. Sil. Syst. 12. f. 11.		*	*			Wenlock Edge, S., Couvin, D.	
19.	— didyma	Dalm. Vet. Acad. Handl. 1827, 6. f. 7; Atrypa id. His. Leth. Suec. 22. f. 7; Sow. Sil. Syst. 6. f. 4; T. corculum, Eichw., referred to the T. sacculus by von Buch; Beitr. Gebirgs. Russland, p. 112.		*	*?			Ludlow, Wenlock, Gottland, S., Ural, D.	
20.	— elongata	Schlot. 20. f. 2? Min. C. 446. f. 2, 3.			*	*		Gründt (Hartz), D., Glücksbrügn.	State of New York.
21.	— explanata	Schlot. 18. f. 2; His. Leth. Suec. 21. f. 11. *c. d.* (an T. prisca, var.?)		*	*			Gottland, West Gottland, S., Eifel, Refrath, Paffrath, D.	Serebrianka.
22.	— ferita	de Buch, Mém. Soc. Géol. France, p. 182, 17. f. 4; Phil. pal. fos. 3. f. 163; Tab. Nos. XXXV. 3 *b. antè*, p. 368.			*			Plymouth, Newton, Barton, Eifel, Villmar.	
23.	— id. var. *a.*	nob. Tab. Nos. XXXV. 3.			*			Eifel.	
24.	— id. var. *b.*	nob. Tab. Nos. XXXV. 3 *a.*			*			ib.	
25.	— galeata	Atrypa gal., Dalm., His. 22. f. 1; Ter. id. de B. loc. cit. suprà, p. 176; Sow. Sil. Syst. 8. f. 10, 12. f. 4; Bronn, 2. f. 9, under the name of Ter. Cassidea; Pentamerus†,		*	*			Dudley, Wenlock, Gottland, S.; Eifel, D.	

† We consider this species as a true Pentamerus.

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		Conrad, States' Report, New York, 1840, p. 202; Sp. plicatus, Stein. loc. cit. p. 359.							
26.	Terebratula Gryphus.	Schlot. Petref. 19. f. 1; Uncites gryphoïdes, Defr. Dict. Sc. Nat.; Ter. Gryphus, Bronn, 2. f. 6; Gypidia gryphoïdes, Gold., Dech.; Handb. p. 527. *antè*, p. 367.	*	*	*	...	...	Salchendorf near Siegen, S.; Paffrath, Villmar, Hagen, Schwelm, Wetzlar, Oberbicht, D.	
27.	— hastata	Min. C. 446. f. 2, 3; Phil. Geol. York. 12. f. 1; id. Pal. fos. 35. f. 168. an T. sacculus?	...	...	*	*	...	Newton, D.; Dublin, Derbyshire, Yorksh., Queen's County, Bristol, Limerick, Visé, Peredki, C.	Chain of Altaï
28.	— Helmersenii	de B. Beitr. Gebirgs. Russland, p. 59	...	...	*	...	...	Lake Ilmen.	
29.	— laticosta	Phil. pal. fos. 34. f. 153.	...	...	*	...	...	Barton.	
30.	— lepida	Gold. Bonn Mus.; nob. Tab. Nos. XXXV. 2 *a, b, c. antè*, p. 368.	...	...	*	...	...	Eifel.	
31.	— lingularis	Münst. Beitr. H. 3. 14. f. 1	...	...	*	...	...	Elbersreuth (Orth. lim.).	
32.	— Livonica	de B. Mém. Soc. Géol. France, 14. f. 5. id. Beitr. Gebirgs. Russ. p. 61.	...	...	*	...	...	Adsel, shore of the Aa, Isborsk.	
33.	— Mantiæ	Min. C. 277. f. 11; Lonsd. Geol. Trans. vol. v. p. 737.	...	...	*	*	...	Plymouth, Newton, Blankenheim, D.; Ireland, C.	
34.	— Meyendorfi	nob. (ined.)	...	...	*	...	...	Volkof, Pskof, Livonia, Vitchedga.	
35.	— monticulata	Schlot. Petref. p. 281. (quoted by M. Hœninghaus, Verst. Samml.)	...	...	*	...	...	Blankenheim, Eifel.	
36.	— nucula	Sow. Sil. Syst. 5. f. 20.	...	*	*	...	...	Ludlow, Dudley, Delbury, S.; Horeb Chapel, Felindre, D.	
37.	— pleurodon	Phil. Geol. Yorks. 12. f. 25, 26, 28; id. Pal. fos. 35. f. 155? T. connivens, Eichw. ap. de B. Beitr. Russl. p. 124.	...	...	*	*	...	Pilton, Croyde, Petherwin, D.; Derbyshire; Yorksh., Whitewell, Coalbrook Dale; Tournay, Visé, Silesia, Lake Seliger, Valdaï, C.	Smeinogorsk in Altaï chain.
38.	— prisca	Schlot. Petref. 17. f. 2; Sow. Geol. Trans. vol. v. p. 703, and de B. loc. cit. p. 176; Atrypa id. Phil. pal. fos. 33. f. 145; Tereb. affinis, Min. C. 324. f. 2; Atry. id. Sow. Sil. Syst. 6. f. 5; Atr. aspera, Sil. Syst. and id. Sow. Geol. Trans. vol. v.; Atry. reticularis, Dalm. apud His. 21. f. 11.; Tereb. id. Bronn, 2. f. 10. (non id. Schlot. and von Buch).	*	*	*	...	...	Siegen, Gottland, West Gottland, St. Petersburg, S.; Thracian Bosphorus, Plymouth, Torquay, Newton, Ferques, Chimay, Couvin, Huy, Eifel, Paffrath, Refrath, Lustheide, Hübigenstein (Hartz), Lake Ilmen, Volkof, Voroneje, D.	Ural, Smeinogorsk (Altaï), State of Ohio, New York, and Tennessee.
39.	— primipilaris	Schlot., de B. 16. f. 16; Atrypa id. Sow. Geol. Trans. vol. v. 57. f. 56; Spir. pentagonus, id. Encyclop. Metrop.; Ter. parallelipipeda, Bronn. Leth. Geog. p. 71, non T. Wilsoni, id.	...	...	*	...	...	Plymouth, Newton, Eifel.	
40.	— id. var. major	nob. T. Wilsoni, Bronn, 2. f. 11; non id. Min. C.	...	...	*	...	...	Bensberg, Eifel.	
41.	— proboscidalis	Phil. pal. fos. 34. f. 149, *a, b.*	...	...	*	...	...	Torquay.	
42.	— pugnus	Min. C. 497; Phil. pal. fos. 35. f. 156; Atrypa id. Sow. Geol. Trans. vol. v. 56. f. 15, 18.	...	...	*	*	...	Plymouth, Newton, Barton, D; Ireland, Tournay, Visé, C.	
43.	— reniformis	Min. C. 496. f. 1–4; id. Phil. pal. fos. 35. f. 157.	...	...	*	*	...	Newton, D.; Dublin, Cork, Whitewell, Yorksh., C.	
44.	— rhomboïdea	Phil. Geol. Yorks. 12. f. 18–20; id. Pal. fos. 35. f. 158.	...	...	*	*	...	Barton, D., Whitewell, Yorksh., C.	
45.	— rotunda	Münst. Beitr. H. 3. 14. f. 15; Atrypa id. Sow. Sil. Syst. 13. f. 7.	...	*	*	...	...	Wenlock Edge, S.; Schübelhammer, D.	
46.	— rotundata	id. 14. f. 3.	...	...	*	...	...	ib. (Clym. lim.).	
47.	— sacculus	Mart. Min. C. 446. f. 1; Phil. Geol. Yorks. 12. f. 2; id. Pal. fos. 35. f. 166; T. hastata, de Buch.	...	...	*	*	*	Barton, D.; Blankenheim, Yorksh., Northumb., Coalbrook Dale, Visé, C.	
48.	— Schnurii	de Vern. Bul. Soc. Géol. Fr., t. xi. 3. f. 2. p. 261.	...	...	*	...	...	Eifel.	
49.	— Stricklandi	Sow. Sil. Syst. 13. f. 19; aff. T. borealis	*	...	...	...	...	Daun, Longhope, Unkel.	
50.	— subglobosa	Gold. (Bonn Mus.)	*	...	...	...	...	Niederosbach.	
51.	— subundata	Münst. Beitr. H. 3. 14. f. 7	...	...	*	...	...	Schübelhammer (Clym. lim.).	
52.	— Virgo	Phil. pal. fos. 35. f. 167.	...	...	*	...	...	Barton, Ferques.	
53.	— Voltzii	nob. Tab. Nos. XXXV. 4 *a, b. antè*, p. 367	...	...	*	...	...	Eifel.	
54.	— Wilsoni	Min. C. 118. f. 3; de Buch, Mém. Soc. Géol. Fr. p. 148; non id. Bronn, Leth. Geog. 2. f. 11; T. lacunosa, Dalm. Vet. Acad. Handl. 1827. 6. f. 6; His. Leth. Suec. 23. f. 3.	...	*	*	...	...	Aymestry, Eastnor Park, west side Malvern Hills, Gottland, Isle of Dago, S.; Chimay, Couvin, Belgium, Néhou, D.	States of Tennessee and Ohio.

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1.	Strigocephalus brevirostris.	Phil. pal. fos. 32. f. 143.			*			Newton.	
2.	— Burtini	Def., Dict. Sc. Nat. Blainv. Man. de Malac. 75; Bronn, Leth. Geog. 2. f. 5; Phil. pal. fos. 32. f. 141; Tereb. rostratus, Schlot. p. 260; Tereb. porrecta, Min. C. 576; f. 1. Tereb. Strigocephalus, de B. Mém. Soc. Géol. Fr. tom. iii. p. 230; Str. giganteus, Sow. Geol. Trans. vol. v. 56. f. 10, 11; Phil. pal. fos. 32. f. 142. *antè*, p. 368.			*			Newton, Bradley, Combe Martin, Hagginton; Chimay, Eifel, Paffrath, Villmar, Wetzler, Dietz, Brilon, Meschede, Martenberg, Schwelm, Weipperfeldt, 19 miles E. of Cologne, banks of the Lahn, Serebrianka.	
3.	— dorsatus	Gold. (Bonn Mus.) nob. XXXV. 5*a*. *antè*, p. 369.			*			Paffrath.	
1.	Pentamerus Knightii	Min. C. 28; Sow. Sil. Syst. 6. f. 8. *antè*, p. 369.	*					Hartz, Greifenstein, Hohenzolen, Aymestry, Sweden.	State of New York.
1.	Atrypa crenulata	Sow. Geol. Trans. vol. v. 56. f. 17; Tereb. id. Phil. pal. fos. 34. f. 152?			*			Plymouth, Barton.	
2.	— cuboïdes	id. ib. 56. f. 24; Tereb. id. Phil. pal. fos. 34. f. 150.			*	*		ib. Hope, Chimay, Eifel, D.; Visé, C.	
3.	— curvata	Ter. curvatus, Schlot. Petref. 19. f. 2. *posteà*, p. 408.	*					District of the Eifel.	
4.	— decussata	id. ib. 54. f. 5; Spirif. id. Phil. pal. fos. 28. f. 120.			*			Petherwin, Brushfort, Baggy Point, Pilton.	
5.	— desquamata	id. ib. 56. f. 19, 20; Phil. pal. fos. 33. f. 146.			*			Plymouth, Newton, Petherwin.	
6.	— fallax	id. ib. 54. f. 15; aff. T. pleurodon			*	* ?		Barnstaple, Petherwin, D.; Yorksh. C.	
7.	— hispida	id. ib. 54. f. 4.			*			Petherwin.	
8.	— impleta	id. 57. f. 2.			*			Plymouth.	
9.	— implexa	id. ib. f. 4.			*			ib.	
10.	— indentata	id. 54. f. 6; aff. A. obovata, Sil. Syst. 8. f. 9.			*			Petherwin, Barnstaple.	
11.	— juvenis	id. 56. f. 8; Tereb. id. Phil. pal. fos. 35. f. 165.			*			Plymouth, Barton.	
12.	— Lacryma	id. ib. f. 9.			*			ib.	
13.	— latissima	id. ib. f. 25; an T. bifera? Phil. pal. fos. 34. f. 151.			*			ib.	
14.	— oblonga	id. 53. f. 6.			*			Barnstaple.	
15.	— plebeïa	id. 56. f. 12, 13; Spirif. id. Phil. pal. fos. 28. f. 121; Tereb. subcurvata, Münst. Beitr. H. 3. 14. f. 4, 5, 6.			*			Plymouth, Barton; Eifel, Elbersreuth.	
16.	— protracta	Sow. Geol. Trans. vol. v. 56. f. 16.			*			ib.	
17.	— sphærica	Sow. Geol. Trans. vol. v. 57. f. 3.			*			Plymouth, D.	
18.	— striatula	id. 54. f. 10. (only a cast)			*			Fowey, Petherwin, Barnstaple.	
19.	— subdentata	id. ib. f. 7; Tereb. id. Phil. pal. fos. 35. f. 164; an Tereb. rotunda? Münst. Beitr. H. 3. 14. f. 15.			*			Petherwin, Schübelhammer?	
20.	— triangularis	Sow. Geol. Trans. vol. v. 54. f. 9.			*			ib.	
21.	— triloba	id. 56. f. 14.			*			ib., Newton.	
22.	— unguiculus	id. ib. f. 8; Spirif. id. Phil. pal. fos. 28. f. 119.			*			Petherwin, Barnstaple, Pilton, Barton, Brushford.	
1.	Spirifer affinis	Sow. Geol. Trans. vol. v. 57. f. 11.			*			Plymouth.	
2.	— aperturatus	Schlot. 17. f. 1; Sow. Geol. Trans. vol. v. p. 704; Phil. pal. fos. 30. f. 133; Trigonotreta id. Bronn, 2. f. 13; Tereb. canalifera, Lam. 2nd ed. tom. vii. p. 341; Delthyris id. Gold., Dech. Handb. p. 526. *antè*, p. 369.			*			Newton; Eifel, Refrath, Paffrath, Linton.	
3.	— id. var. *a*. cuspidatus.	nob. Tab. Nos. XXXV. 7 *a*			*			Paffrath, Refrath.	
4.	— id. var. echinulatus	nob. Tab. Nos. XXXV. 8 *a*			*			Bensberg.	
5.	— Archiaci	Murch. Bul. Soc. Géol. France, t. xi. 2. f. 4, p. 252.			*			Ferques, Tatimont, Chimay, Voroneje.	
6.	— Bouchardii	id. ib. f. 5. p. 253.			*			ib., Chimay.	
7.	— calcaratus	Sow. Geol. Trans. vol. v. 53. f. 7. an. Sp. Verneuili?			*			Barnstaple.	
8.	— id. var. *a*, *b*, *c*	Phil. pal. fos. 29. f. 128.			*			Petherwin, Taunton, Pilton, Baggy Point, Hope, Yealmpton.	
9.	— Cheiropteryx	nob. Tab. Nos. XXXV. 6, *a*, *b*. *antè*, p. 370.			*			Paffrath.	
10.	— connivens	Phil. Geol. Yorks., Part 2. 11. f. 2. *antè*, p. 371.			*	*		Ferques, Eifel, Paffrath, D.; Visé, Yorkshire, C.	
11.	— costatus	Sow. Geol. Trans. vol. v. 55. f. 5–7; Phil. pal. fos. 30. f. 134.			*			Tintagel, Fowey, Torquay, Meadfoot Sands.	
12.	— crispus	Sow. Sil. Syst. 12. f. 8; Delthyr. id. Dalm.; His. Leth. Suec. 21. f. 5.		*	*	*		Wenlock, Gottland, S.; Eifel, Sötenich, D.; Ratingen, Visé, C.	
13.	— curvatus	Schlot. Petref. 19. f. 2.			*			Paffrath, Eifel.	

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14.	Spirifer cuspidatus...	Min. C. 120, 461. f. 2; Phil. Geol. Yorks. 9. f. 1–4; id. Pal. fos. 29. f. 124 β; Delthyris id. Conrad, States' Report, New York, 1838, p. 109. Often confounded with var. *a.* of S. aperturatus.	...	...	*	*	...	Barton, Rocquigny, Eifel, Sötenich, D.; Bolland, Settle, Derbysh., Kildare, Ireland, Tournay, Sablé, C.	Davidson County, State of New York.
15.	— disjunctus	Sow. Geol. Trans. vol. v. 53. f. 8. id. 54. f. 12, 13; Phil. pal. fos. var. 29. f. 128, 129. *an* a variety of Sp. Verneuili?	...	...	*	...	...	Petherwin, Barnstaple, Torquay, Baggy Point, Yealmpton.	
16.	— distans	Min. C. 494. f. 3; Phil. pal. fos. 29. f. 128. *f, g, h.*	...	...	*	*	...	Torquay, Newton, D.; Dublin, Bolland, C.	
17.	— extensus.....	Sow. Geol. Trans. vol. v. 54. f. 11.....	...	...	*	...	...	Barnstaple, Petherwin, Taunton.	
18.	— giganteus	id. ib. 55. f. 1; Phil. pal. fos. 30. f. 130. ...	...	...	*	...	...	Tintagel, Petherwin.	
19.	— glaber	Min. C. 269. f. 1; Ter. lævigatus, Schl. p. 257. *antè* p. 370.	...	...	*	*	*	Sötenich, Bensberg? Hübigenstein (Hartz), D.; Ireland, I. of Arran, I. of Man, Bolland, Liège, Ratingen, Serpoukof, Sablé, C.	State of the Ohio.
20.	— id. var. minor	nob.	...	...	*	...	...	Paffrath.	
21.	— grandævus	Phil. pal. fos. 30. f. 131.	...	...	*	...	...	Petherwin.	
22.	— heteroclitus	de Blainv.; Malac. 50. f. 3; de Buch, Mém. Soc. Géol. France, iv. 8. f. 11; Calceola id. Defr. Dict. Sc. Nat.; Phil. pal. fos. 29. f. 125. *antè*, p. 370.	...	...	*	...	...	Barton, Newton; Chimay, Eifel, Villmar, Ferques.	
23.	— hirundo	Phil. pal. fos. 28. f. 122. *a, b, c.*	...	...	*	...	...	Hope, near Torquay.	
24.	— intermedius	Schlot. 16. f. 2. an S. speciosus, var.?.....	*	*	*	...	...	Coblentz, Abentheuer, Gloucestersh.? Herefordsh.? S.; Eifel, Hartz, D.	Mount Alleghany.
25.	— inornatus	Sow. Geol. Trans. vol. v. 53. f. 9.	...	...	*	...	...	Ilfracombe.	
26.	— lineatus	Tereb. id. Min. C. 334. f. 1, 2; Spirifer Index, Phil. Geol. Yorks. 10. f. 17; id. Pal. fos. 28. f. 120 *a*, and 58. f. 120*.	...	...	*	*	...	Petherwin, D.; Kirkby Lonsd., Northumb., Derbysh., Visé, C.	
27.	— Lonsdalii	Murch. Bul. Soc. Géol. de France, t. xi. 2. f. 2. p. 251.	...	...	*	...	...	Ferques, Chimay.	
28.	— macropterus	Gold., Leonh. Taschenb. t. vii.; an S. micropterus? id., an S. speciosus? var.	*	*	*	...	...	Houffalize, Wiltz, Long Wily, in the Ardennes, Kemmenau, Lahn mouth, Siegen, Braubach, Mosell, Heigerselbach, S.; Eifel, Dombrowa near Kielce, Schwelm, Goslar, D.	Mount Cedar in South Africa; Kunawa in the Himalaya; States of the Ohio and New York.
29.	— mediotextus	nob. Tab. Nos. XXXV. 9 *a, b, c, antè*, p. 370.	...	...	*	...	...	Eifel.	
30.	— megalobus	Phil. pal. fos. 31. f. 140.	...	...	*	...	...	Brushford.	
31.	— mesomalus	id. ib. 31. f. 137.	...	...	*	...	...	ib.	
32.	— micropterus	Goldf. Hysterolites hystericus, Schlot. Petref. 29. f. 1. *posteà*, p. 408.	*	...	...	...	...	Kaysersteinel.	
33.	— minimus.....	Min. C. 377. f. 1. (S. acutus, Flem. Brit. Anim. p. 375.)	...	...	*	*	...	Blankenheim? D., Derbyshire, C.	
34.	— Murchisonianus...	de Kon. (ined.)	...	...	*	...	...	Chimay, Ural.	
35.	— microgemma	Phil. pal. fos. 27. f. 116, *a, b.*	...	...	*	...	...	Brushford, Hope, near Torquay.	
36.	— nudus	Sow. Geol. Trans. vol. v. 57. f. 8; Phil. pal. fos. 31. f. 138.	...	...	*	...	...	Plymouth, Torquay.	
37.	— oblatus	Min. C. 268; Sow. Geol. Trans. vol. v. p. 704; Trigonotreta id. Bronn, 2. f. 16; S. obtusus, Min. C. 269. (lower figures)	...	...	*	*	*	Newton, Torquay, Eifel, D.; Ireland, Derbysh., Visé, Ratingen, C.	Van Diemen's Land.
38.	— obliteratus	Phil. pal. fos. 31. f. 135.	...	...	*	...	...	Brushford. [Derbysh., C.	
39.	— octoplicatus	Min. C. 562. f. 2–4; Sow. Sil. Syst. 12. f. 7.	...	*	*	*	...	Wenlock, Mondrepuis, S.; Eifel, D.;	
40.	— ostiolatus	Tereb. id. Schlot. 17. f. 3; id. Stein. Mém. Soc. Géol. France, t. 1. p. 359; Sow. Geol. Trans. vol. v.; Phil. pal. fos. 30. f. 132; Trigonotreta id. Bronn, 2. f. 14; Delthyris lævicosta, Gold., Dech. Handb., p. 525.	*	*	*	...	...	Daun, S.; Newton, Linton, Eifel, Chimay, Huy, Couvin, D.	
41.	— phalæna	Phil. pal. fos. 28. f. 123.	...	...	*	...	...	Hope, near Torquay.	
42.	— plicatus?.....	Hœn. Verst. Sammlung.	...	...	...	...	*	Ratingen.	
43.	— protensa	Phil. pal. fos. 28. f. 118.	...	...	*	...	...	Petherwin.	
44.	— ptychodes	Sow. Sil. Syst. 3. f. 13; Delthyris id. Dalm.; His. Leth. Suec. 21. f. 8.	...	*	*	...	...	Fownhope, &c., S.; Felindre, D.	
45.	— pulchellus	Sow. Geol. Trans. vol. v. 57. f. 9.....	...	...	*	...	...	Plymouth.	
46.	— resupinatus	Tereb. vestitus and similis, Schlot. 15. f. 1, 2; Anom. resupin. Mart. Pet. Derb. 49. f. 13, 14; Tereb. id. M. C. 325; Phil. Geol. Yorks. 11. f. 1; Orthis id. pal. fos. 27. f. 119. *antè*, p. 371.	...	...	*	*	*	Newton, Barton, Mettmann, D.; Ireland, Derbyshire, Otterburn, Bolland, Visé, Ratingen, Sablé, C.	State of New York.

No. of Species.	Genera and Species.	Authors and References. The numerals refer to Species described and figured in this Memoir.	Sil. Sp. in Rhen. Prov.	Dev. & Sil. Sp.	Devonian Sp.	Dev. & Carb. Sp.	Carb. Sp.	Localities in Europe.	Elsewhere.
47.	Spirifer rotundatus...	Min. C. 461. f. 1; Phil. Geol. Yorks. 9. f. 17; id. Pal. fos. 31. f. 139.	.....	...	*	*	...	Barton, D.; Bolland, Queen's County, C.	
48.	— rudis ?.....	Phil. pal. fos. 31. f. 136.	.....	...	*	...	...	Baggy Point.	
49.	— simplex	id. ib. 29. f. 124 *α*, 60. f. 124*.....	.....	...	*	...	...	Plymouth, Newton.	
50.	— speciosus	Tereb. id. Schlot. 16. f. 1; Spirif., de B. Mém. Soc. Géol. France, t. iv.; id. Phil. pal. fos. 58. f. 134*; id. Sow. Geol. Trans. vol. v.; Hysterolites paradoxus, vulvarius, Schlot.; Trigonotreta speciosa, Bronn, Leth. Geog. 2. f. 15; König. Icon. Foss. Sect. 6. f. 71. Tab. XXXVIII. 5. *posteà*, p. 408.	*	*	*	...	...	Daun, Coblentz, Hickenvaghen, Auberlanstein near Mayence, S.; Newton, Torquay, Couvin, Eifel, Luga, D.	Ural, Cedar Mountain in South Africa.
51.	— striatulus	Tereb. id. Schlot. 15. f. 4; T. excisus, id. 15. f. 3; Atr. polygramma, Sow. Sil. Syst. 21. f. 4, *a*.	.....	*	*	*	...	Powis Castle, S.; Chimay, Ferques, Huy, Eifel, Hartz, Volkof, Ural, D.; Yorkshire, C.	State of New York.
52.	— subconicus	Anom. id. Mart. Pet. Derb. 45. f. 6; Spirifer id. Sow. Geol. Trans. vol. v. 57. f. 10; Phil. pal. fos. 29. f. 126.	.....	...	*	*	...	Plymouth, Newton, Barton, Eifel, D.; Derbysh., C.	
53.	— superbus.....	Eichw., see von Buch, Beitr. Gebirgs. Russland, p. 111. (affinis Sp. striatus).	.....	*?	*?	...	...	.....	Bogoslofsk, Ural.
54.	— trapezoïdalis	Sow. Sil. Syst. 5. f. 14; id. Geol. Trans. vol. v. p. 704; Cyrtia id., Dalm.; His. 21. f. 1; id. Bronn, 3. f. 3; Delthyris id. Gold. Dech. Handb. p. 525. *antè*, p. 370.	.....	*	*	...	...	Lake Ilmen, Luga, Usk, Malvern Hills, Gottland, S.; Newton, Couvin, Eifel, Paffrath, Pokroi, D.	
55.	— Verneuili	Murch. Bul. Soc. Géol. de France, t. xi. 2. f. 3. p. 252; an Sp. calcaratus et disjunctus?	.....	...	*	...	...	Ferques, Tatimont, Chimay, Rhisnes near Namur, Golzines, Voroneje.	Smeinogorsk in Altaïchain, Berosova (Siberia).
56.	— id. var.	id. ib. f. 3 *b*.....	.....	...	*	...	...	Ferques, Tatimont (Nord), Chimay.	
57.	— vetulus	Eichw., see von Buch, Beitr. Gebirgs. Russland, p. 112.	.....	*?	*?	...	...	.....	Bogoslofsk (Ural).
1.	Orthis Actoniæ	Sow. Sil. Syst. 20. f. 16; Tab. XXXVIII. 14.	*	...	...	...	...	Braubach, Siegen, Horderley, flanks of the Caradoc, near Carmarthen.	
2.	— antiquata	Sow. Sil. Syst. 13. f. 13.	.....	*	*	...	...	Chimay, Couvin, Woolhope, S.	
3.	— arcuata	Phil. pal. fos. 26. f. 107.	.....	...	*	...	...	Hope.	
4.	— Arimaspus †	Eichw., von Buch, loc. cit. suprà, p. 108, 112. (affinis O. flabellulum, aff. Buch).	.....	*?	*?	...	...	.....	Bogoslofsk.
5.	— calcar	Phil. pal. fos. 58. f. 112*	.....	...	*	...	...	Pilton.	
6.	— circularis	Sow. Tab. XXXVIII. f. 12.	.....	...	*	...	...	Daun.	
7.	— concentrica	Münst. Beitr. H. 3. 14. f. 19.	.....	...	*	...	...	Elbersreuth (Orth. lim.).	
8.	— costata	Sow. Sil. Syst. 21. f. 11; id. Münst. Beitr. H. 3. 14. f. 18.	.....	*	*	...	...	Geiser, near Hof, also near Welshpool, S. (Clym. lim.)	
9.	— demissa	Dalm.; His. 20. f. 14; O. moneta, Eichw., see von Buch, Beitr. Gebirgs. Russland, p. 19; Productus extensus, hamatus, pteratus, pterygoïdeus, coracoïdeus, oblongus, elevatus, orbicularis, and semicircularis, Pander, Beitr. Russ. Reiches., p. 89 *et seq.*	.....	*	*	...	...	Oeland, St. Petersburg, S.; Verviers, D.	
10.	— Dutertrii	Murch. Bul. Soc. Géol. France, t. xi. 2. f. 6. p. 253.	.....	...	*	...	...	Ferques, Voroneje.	
11.	— expansa	Sow. Sil. Syst. 20. f. 14; Tab. Nos. XXXVIII. 12.	*	...	...	...	...	Sulbach (Hartz) near Guilsfeld.	
12.	— fasciculata	Gold. (Bonn. Mus.)	*	...	...	...	...	Ems, Eigerselbach.	
13.	— flabellulum.....	Sow. Sil. Syst. 21. f. 8. non 19. f. 8; O. callactis, Dalm.; His. 20. f. 9; Tab. XXXVIII. 13, *posteà*, probably only varieties of O. demissa.	*	...	...	...	...	Daun, Braubach, Siegen, Corton.	
14.	— grandis	Sow. ib. 20. f. 12, 13.	*	...	...	...	...	Siegen, Horderley, &c.	
15.	— granulata	Münst. Beitr. H. 3. 14. f. 17.	.....	...	*	...	...	Schübelhammer.	
16.	— granulosa	Phil. pal. fos. 26. f. 111.	.....	...	*	...	...	Woodabay, Meadfoot Sands.	
17.	— Hardrensis.....	Phil. pal. fos. 58. f. 104*; 60. f. 104*	.....	...	*	...	...	Berry Pomeroy, D.; Westleigh, Hardrow, C.	
18.	— hians	de B. Mém. Soc. Géol. de France, t. iv. 11. f. 14.	.....	...	*	...	...	Berendorf, in the Eifel.	
19.	— hybrida	Sow. Sil. Syst. 13. f. 11.	.....	*	*	...	...	Walsall, Staffords., S.; Chimay, Couvin, [D.	State of New York.
20.	— interlineata	Sow. Geol. Trans. vol. v. 53. f. 11, and 54. f. 145; Phil. pal. fos. 26. f. 106.	.....	...	*	...	...	Petherwin, Brushford, Landlake, Leary, &c., Combe, C.	

† We believe that it is a Terebratula.

No. of Species.	Genera and Species.	Authors and References. The numerals refer to Species described and figured in this Memoir.	Sil. Sp. in Rhen. Prov.	Dev. & Sil. Sp.	Devonian Sp.	Dev. & Carb. Sp.	Carb. Sp.	Localities in Europe.	Elsewhere.
21.	Orthis interstrialis ...	Phil. pal. fos. 26. f. 103	.....	...	*	...	...	Barton.	
22.	— lens	Phil. pal. fos. ib. 26. f. 110.....	.....	...	*	...	...	Hope, near Torquay.	
23.	— lepis	Strophomena id. Bronn, Leth. Geog. 2. f. 7; Productus elegans, de Hüpsch, Naturg. Niederd. 1. f. 78; Stein. Mém. Soc. Géol. France, t. i. p. 361; Tab. Nos. XXXVI. 4 *a. antè*, p. 372.	.....	...	* *	...	...	Eifel.	Kentucky.
24.	— longisulcata	Phil. pal. fos. 26. f. 105.	.....	...	*	...	...	Linton, Watersmeet, Woodabay.	
25.	— lunata.....	Sow. Sil. Syst. 3. f. 12, *d*, and 5. f. 15.	*	*	*	...	...	Ludlow, Ems, Daun, Grünenwald, Ehrenbreitstein, banks of Moselle, S.; Horeb Chapel, Eifel, D.	
26.	— micans	de Buch, Beitr. Geb. in Rus. p. 56.	.....	...	*	...	...	Volkof.	
27.	— minuta	Gold., de Buch, Mém. Soc. Géol. France, t. iv. p. 217; Tab. Nos. XXXVI. 5 *a*, *b*. p. 372.	.....	...	*	...	...	Eifel.	
28.	— Murchisoni	nob. Tab. Nos. XXXVI. f. 2. *antè*, p. 371....	*	...	...	...	...	Siegen.	
29.	— nucleiformis	Schlot. (coll.); de Buch, Mém. Soc. Géol. France, t. iv. p. 212. (only a cast)	.....	...	*	...	...	Eifel.	
30.	— orbicularis	Sow. Sil. Syst. 5. f. 16.....	*	...	...	...	...	Ludlow, &c., S.	State of New York.
31.	— id. var.†.....	Murch. Bul. Soc. Géol. de France, t. xi. 11. f. 8. p. 255.	.....	...	*	...	...	Ferques.	
32.	— obovata	J. Sow. Tab. XXXVIII. f. 10. *posteà*, p. 409.	*	...	...	...	...	Haiger Sülbach, near Dillenburg.	
33.	— partita	id. Tab. XXXVIII. f. 11. *posteà*, p. 409.....	*	...	...	...	...	ib.	
34.	— parallela.....	Phil. pal. fos. 26. f. 109.	.....	...	*	...	...	Petherwin, Pilton, Brushford.	
35.	— pecten.....	Dalm., His. 20. f. 6; Sow. Sil. Syst. 21. f. 9; J. Sowerby, Tab. XXXVIII. f. 9? *posteà*, p. 409.	*	...	...	...	...	Braubach, Heissenstein, Niederosbach, mouth of Lahn, Sülbach (Hartz), Gottland, East Gottland, Mondrepuis, Horderley, Shropshire, &c.	North America.
36.	— plicata	Sow. Geol. Trans. vol. v. 53. f. 10; Phil. pal. fos. 26. f. 108.	.....	...	*	...	...	Barnstaple, Brushford, Ashburton, Meadfoot Sands.	
37.	— productoïdes	Murch. Bul. Soc. Géol. de France, t. xi. 2. f. 7. p. 254.	.....	...	*	...	...	Ferques, Couvin, Eifel, Voroneje.	
38.	— rugosa	de B. Mém. Soc. Géol. de France, t. iv.; Leptæna id. Dalm., His. 20. f. 2; Phil. pal. fos. 24. f. 95; Sow. Geol. Trans. vol. v. 56. f. 4; Strophomena id. Bronn, 2. f. 8; de Hüpsch, loc. cit. suprà; id. Rafinesque; Lept. depressa, Sow. Min. C. 459. f. 3.	.....	*	*	...	...	Sötenich, Gottland, St. Petersburg, S.; Plymouth, Newton, Verviers, Eifel, D.	Mount Catskill, Trenton Falls, Pennsylvania.
39.	— sericea	de Buch, Mém. Soc. Géol. de France, t. iv. (an Lept. id. Sow. Sil. Syst.)	.....	...	*	...	...	Schweidnitz (Silesia).	
40.	— Sedgwickii	nob. Tab. Nos. XXXVI. f. 1. *antè* p. 371....	*	...	...	...	...	Siegen, Landerskron.	
41.	— semicircularis.....	Sow. Sil. Syst. 21. f. 7; Münst. Beitr. H. 3. 14. f. 16.	.....	*	*	...	..	Cornden or Shelve Hills, S.; Pilton, Schübelhammer, D.	
42.	— ? strigosa.....	J. Sow. Tab. XXXVIII. f. 7. *posteà*, p. 409.	*	...	...	...	...	Haiger Sülbach, near Dillenburg.	
43.	— subarachnoïdea ...	nob. (O. arachnoïdea, Phil. pal. fos. 27. f. 114; non Spirif. id. Geol. Yorks. xi. f. 4; Tab. Nos. XXXVI. f. 3.) *antè*, p. 372.	*	*	*	...	...	Kemmenau, Ems, S., Hope, D.	
44.	— tenuistriata	Sow. Geol. Trans. vol. v. 57. f. 12. an Orth. arachnoidea?	.....	...	*	...	...	Morebath.	
45.	— testudinaria	Dalm., His. 20. f. 11; Sow. Sil. Syst. 20. f. 9, 10; Trigonotreta id. Bronn, Leth. Geog. 3. f. 2.	.....	*	*	...	...	Flanks of the Caradoc, &c., East Gottland, Mondrepuis, S.; Eifel, D.	Trenton Falls, State of the Ohio.
46.	— umbraculum	Hüpsch, Nat. Gesch. vol. i. 1. f. 1, 2; Schl. p. 256; O. pecten, Linn. and Fisch.; Index Oryct. Govern. de Mosc. 20. f. 5, 6, p. 145; Strophomena pileopsis, Raf., De la Beche Manuel, Hœn.; Spirifer and Ort. crenistria, Phil. Geol. Yorks. 9. f. 6; id. Pal. fos. 27. f. 113; id. Sow. Geol. Trans. vol. v. 57. f. 7; Sp. reticulata, Sow. Encycl. Metropol., art. Geology.	.....	...	*	*	...	Plymouth, Ferques, Eifel, D.; Ireland, Yorksh., Visé, Tournay, Valdaï, Peredki, Volkofskaïa, Moscow, C.	Kentucky.
47.	— virgulata.....	J. Sow. Tab. XXXVIII. f. 8. *posteà*, p. 409.	*	...	...	...	...	Haiger, Sülbach, near Dillenburg.	
48.	— Witryana	de Kon. (ined.)	.....	...	*	...	...	Chimay, Couvin.	
1.	Leptæna analoga ...	Phil. pal. fos. 24. f. 93; Producta id. Geol. Yorks. 7. f. 10.	.....	...	*	*	...	Barnstaple, Croyde, Pilton, D.; Ireland, Yorksh., Derbysh., Northumberland, C.	State of New York.

† It deserves another name, as it is quite different from the *O. orbicularis*, Sow., and not a variety only.

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2.	Leptæna caperata ...	Sow. Geol. Trans. vol. v. 53. f. 4; Phil. pal. fos. 25. f. 98.	...	...	*	...	...	Petherwin, Barnstaple, Croyde, Pilton; Prussino near the Volkof, Buregi, Lake Ilmen.	Altaï chain.
3.	— convoluta	Phil. pal. fos. 24. f. 96.	...	...	*	...	...	Croyde Bay.	
4.	— explanata	J. Sow. Tab. XXXVIII. f. 15. *posteà*, p. 409.	*	...	...	...	...	Daun.	
5.	— fragaria	Sow. Geol. Trans. vol. v. 56. f. 5; Phil. pal. fos. 25. f. 100.	...	...	*	...	...	Petherwin, Newton, Hope, Plymouth.	
6.	— interrupta	Sow. Geol. Trans. vol. v. 56. f. 7.	...	...	*	...	...	Plymouth.	
7.	— membranacea.....	Phil. pal. fos. 25. f. 101 *a*.	*	*	*	*	*	Pilton, Petherwin.	South Africa,
8.	— nodulosa.....	id. ib. 24. f. 94.	...	...	*	...	...	Newton, Hope, Eifel.	New York.
9.	— prælonga	Sow. Geol. Trans. vol. v. 53. f. 29. *posteà*, p. 409.	...	...	*	...	...	Croyde Bay.	
10.	— profunda	J. Sow. Tab. XXXVIII. f. 13. *posteà*, p. 409.	...	...	*	...	...	Olpe.	
11.	— plicata	id. Tab. XXXVII. f. 16. *a–c. posteà*, p. 409.	*	...	...	...	...	Haustig, near Siegen.	
12.	— semiradiata	id. Tab. XXXVIII. f. 14. *a–e. posteà*, p. 409.	*	...	...	...	...	Prüm.	
13.	— sarcinulata.....	Hüpsch. Schlot.; Petref. 29. f. 3. Orthis striatella, Dalm. His. Leth. Suec. 20. f. 7; Lept. lata, Buch; id. Sow. Sil. Syst. 3. f. 10 *b*. and 5. f. 13.	*	*	*	*	*	Ludlow Promontory, Ems, Daun, Prüm, Lahn mouth, Kemmenau, Hundsruck, Taunus, Ebersdorf, Gottland, Coblentz, Malmö, Pokroi, S; Felindre, Horeb Chapel, Eifel, D; Visé, Tournay, Dwina, South of Archangel, C.; Elberfeld Malmedy.	
14.	— sericea	Sow. Sil. Syst. 19. f. 2; *antè*, p. 372; Strickland, Geol. Trans. vol. v. p. 387.	*	...	...	...	...	Braubach, Prüm, Llandovery, Horderley, &c., Thracian Bosphorus.	State of New York.
15.	— sordida	Sow. Geol. Trans. vol. v. 53. f. 5; Orthis sordida, Phil. pal. fos. 25. f. 104.	...	...	*	...	...	Linton, Torquay.	
16.	— striata.....	Gold. (Bonn Mus.)	*	...	...	...	...	Kemmenau.	
1.	Producta antiquata...	Min. C. 317. f. 1. 5, 6.	...	...	...	...	*	Ratingen, Sablé, Ireland, Yorksh., Derbysh., Visé, Moscow, Valdaï, Zaraïsk, banks of the Dwina, Silesia, S.	
2.	— comoïdes	ib. 329.	...	...	...	...	*	Ratingen, Yorksh., Visé, Moscow.	State of the
3.	— concinna.....	ib. 318. f. 1; id. Phil. Geol. Yorks. 7. f. 9...	...	...	...	...	*	Ratingen, Ireland, Yorksh., Derbys., Valdaï, Pinega, Visé.	Ohio.
4.	— fimbriata.....	ib. 459. f. 1.	...	...	...	...	*	Ratingen, Yorkshire, Isle of Man, South of Ireland, Visé.	
5.	— hemispherica	Min. C. 328.	...	...	...	...	*	ib., Liège, Visé, Coalbrook Dale.	
6.	— latissima.....	ib. 330.	...	...	...	...	*	ib., Yorksh., Northumb., Anglesea, Liège, Visé, Silesia, Russia.	
7.	— laxispina.....	Phil. Geol. Yorks. 8. f. 13; id. Leptæna, Pal. fos. 25. f. 99.	...	...	*	*	...	Petherwin, D.; Moulton, Yorks., C.	
8.	— lobata.....	ib. 318. f. 2, 3, 4, 5.	...	...	...	...	*	Ratingen, S.; Arran, Otterburn, Northumb., Ireland, Liège, Visé, Pinega.	State of the Ohio.
9.	— margaritacea	Phil. Geol. Yorks. 8. f. 8.	...	...	...	...	*	Falckenberg (Silesia), Yorksh., Visé.	
10.	— Martini	Min. C. 317. f. 2, 3, 4.	...	...	...	...	*	Ratingen, Ireland, Yorkshire, Northumb., Visé, Valdaï.	
11.	— plicatilis	ib. 459. f. 2.	...	...	...	...	*	Ratingen, Yorksh., Visé, Liège.	
12.	— punctata.....	ib. 323; Leptæna sulcata, Fisch. Oryct. Govern. de Moscou, 23. f. 2. p. 143.	...	...	...	...	*	ib. ib., Cork, Visé, Liège, Sablé, Valdaï, Moscow, Dwina, Pinega.	State of the Ohio.
13.	— scabricula	Min. C. 69; Phil. Geol. Yorks. 8. f. 2; id. pal. fos. 24. f. 87.	...	...	*	*	...	Pilton, Brushford, D.; Yorksh., Derbysh., Bristol, Coalbrook Dale, Liège, Visé, Peredki, C.	State of the Ohio and New York.
14.	— spinulosa	Min. C. 68. f. 3.	...	...	*	*	*	Refrath, Gladbach, D.; Ratingen, Visé, Yorkshire, Linlithgowshire, C.	
15.	— subaculeata	Murch. Bul. Soc. Géol. de France, t. xi. 2. f. 9. p. 255.	...	...	*	...	...	Ferques, Chimay, Couvin, Eifel, Kirspenich, Cronenburg, Aggerthal.	
	Monomyaria.								
1.	Ostrea? (ind.).....	Quoted by M. Beyrich, Verst. Rhein., p. 16.	...	...	*?	...	...	Villmar.	
1.	Pecten alternatus ...	Phil. pal. fos. 21. f. 78.	...	.	*	...	...	Petherwin.	
2.	— Altonis	Gold. 160. f. 5.	*?	..	...	...	...	Glatz (Silesia).	
3.	— arachnoïdeus	Phil. pal. fos. 21. f. 80.	...	.	*	...	...	Petherwin.	
4.	— arenosus.....	Phil. Geol. Yorks., 6. f. 20; Sow. Geol. Trans. vol. v. 703*.	...	...	*	...	...	Plymouth, D.; Bolland, Derbysh., C., &c.	
5.	— grandævus	Gold. 88. f. 9.	...	...	...	...	*	Herborn.	
6.	— granulosus	Phil. pal. fos. 21. f. 75.	...	...	*	...	...	Petherwin.	
7.	— Hasbachii	nob. Tab. Nos. XXXVI. f. 13. *antè*, p. 372.	...	...	*	...	...	Refrath.	
8.	— Ingriæ	nob. (ined.)	...	...	*	...	...	Volkof.	

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9.	Pecten linteatus	Gold. Petref. Germ. 114. f. 9. (quoted by M. Beyrich Verst. Rhein., &c., p. 17.)			*	*	*	Amay (Belgium), D.; Herborn, C.	
10.	— Munsteri	H. V. Meyer.					*	Herborn.	
11.	— nexilis	Sow. Geol. Trans. vol. v. 53. f. 1, 2.			*			Barnstaple.	
12.	— oceani	Gold. 88. f. 10.			*			Eifel, Goslar.	
13.	— Phillipsii	ib. 160. f. 6.	*?					Glatz.	
14.	— plicatus	Min. C. 574. f. 3; Phil. 6. f. 21; id. pal. fos. 60. f. 80*.			*	*		Plymouth, Newton, D.; Queen's County, C.	
15.	— polytrichus	Phil. pal. fos. 21. f. 76.			*			Brushford.	
16.	— id. var. *b.*	id. ib.			*			Mudstone Bay.	
17.	— primigenius	H. v. Meyer., loc. cit. suprà.					*	Herborn.	
18.	— rugosus	Phil. pal. fos. 21. f. 79.			*			Babbacombe.	
19.	— striolatus	Gold. 160. f. 7.			*			Eifel.	
20.	— transversus	Sow. Geol. Trans. vol. v. 53. f. 3; id. Phil. pal. fos. 21. f. 77, an Avic. radiata, Gold.? and Phil. Geol. Yorks. 6. f. 8.			*	*		Barnstaple, Pilton, Brushford, Croyde, Petherwin, Eifel, Iserlohn, D.; Bolland, C.	
21.	— trifidus	de Buch, über Gon. und Clym. in Schl. 1839, p. 19, or Abhandl. Kön. Wiss., Berlin, 1838, p. 167.					*	Falckenberg, Silesia.	
22.	— (ind.)	id. ib. f. 14.					*	ib.	
1.	Posidonia Becheri	Gold. 113. f. 6; Bronn, Miner. Jahr. 1828. 2. f. 1–4; Sow. Geol. Trans. 52. f. 2, 3, 4; Phil. pal. fos. 20. f. 73; Bronn, 2. f. 17.					*	Herborn, Frankenberg (Hesse), Ründeroth, Beringhausen, Schelke, Venn, Swimbridge, Lew Trenchard, Truscott, Edderbringhausen, Hesse Cassel, Oberschulenberg, Bocksviese, near Clausthal.	
2.	— elegans	Posidonomya, Münst. Beitr. H. 3. 10. f. 9.			*			Gattendorf.	
3.	— grandis	id. ib. f. 10.			*			ib.	
4.	— longitudinalis	Bronn, Leth. Geogn. p. 89, perhaps a variety of P. Becheri.					*	Herborn.	
5.	— myacea	an Mytiloïdes? Gold. (Coll.), *antè*, p. 374.			*			Eibach.	
6.	— nobilis	Posidonomya, Münst. Beitr. H. 3. 10. f. 8.			*			Gattendorf.	
7.	— scalaris	id. ib. p. 51.			*			ib.	
8.	— semistriata	id. ib. f. 11.			*			Schübelhammer (Clym. lim.).	
9.	— venusta	id. ib. f. 12.			*			ib.	
1.	Avicula aculeata	Gold. 160. f. 8.			*			Eifel.	
2.	— anisota	Phil. pal. fos. 22. f. 83.			*			Meadsfoot Sands.	
3.	— antiqua	Gold. 160. f. 9.			*			Eifel.	
4.	— cancellata	Phil. pal. fos. loc. cit. 22. f. 84.			*			Baggy Point, Croyde, Braunston.	
5.	— Damnoniensis	Sow. Geol. Trans. vol. v. 53. f. 22; Phil. pal. fos. 23. f. 90–92.			*			Marwood.	
6.	— id. var.	id. ib.			*			ib.	
7.	— elongata	Münst. Beitr. H. 3. 11. f. 2. (Monotis)			*			Geiser.	
8.	— exarata	Phil. pal. fos. 23. f. 89.			*			Petherwin.	
9.	— gibbosa	Münst. Beitr. H. 3. 11. f. 4.			*			Schübelhammer (Clym. lim.).	
10.	— Goldfussii	nob. Tab. Nos. XXXVII. f. 15 *a. antè*, p. 373.			*			Paffrath, Refrath.	
11.	— inflata	Münst. Beitr. H. 3. 11. f. 5.			*			Presseck.	
12.	— lepida	Gold. 116. f. 2.					*	Herborn.	
13.	— Neptuni	id. ib. f. 4.			*			Eifel.	
14.	— obsoleta	id. ib. f. 1.	*					Abenthaeur (Hundsruck).	
15.	— papyracea	id. ib. f. 5; Pecten, Min. C. 354, and Phil. Geol. Yorks., p. 213.					*	Werden, Essen, Liège, Bolland, Coalbrook Dale.	
16.	— pectinoïdes	Sow. Geol. Trans. vol. v. 54. f. 2.			*			Petherwin, Barnstaple.	
17.	— problematica	Münst. Beitr. iii. 11. f. 6.			*			Presseck (Clym. lim.).	
18.	— rectangularis	Sow. Sil. Syst. 3. f. 2.			*			Horeb Chapel, Eifel.	
19.	— reticulata	His. Leth. Suec. 17. f. 13; Sow. Sil. Syst. 6. f. 3; Pterinea id. Gold. 120. f. 2.	*	*	*			Gottland, West Gottland, Aymestry, Croft Valley, Mondrepuis, S.; Eifel, Hagen, Elberfeld, Iserlohn, Newton, Barton, Eifel, D.	
20.	— rudis	Phil. pal. fos. 22. f. 85.			*			Brushford, Pilton.	
21.	— rugosa	Münst. Beitr. H. 3. 11. f. 3. (Monotis)			*			Schübelhammer.	
22.	— Saturni	Gold. 116. f. 3.			*			Eifel.	
23.	— semialata	Münst. Beitr. H. 3. 11. f. 7.			*			Elbersreuth (Clym. lim.).	
24.	— semiauriculata	id. ib. 11. f. 1. (Monotis, Bronn)			*			Geiser (Clym. lim.).	
25.	— subradiata	Sow. Geol. Trans. vol. v. 54. f. 1; Phil. pal. fos. 23. f. 90–92.			*			Petherwin.	
26.	— texturata	Phil. pal. fos. 23. f. 87.			*			Barton.	

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27.	Avicula tumida	de B. Abhandl. Kön. Akad. Wiss. Berlin, 1838, f. 13.					*	Falckenberg, Silesia.	
28.	— (ind.)	id. Geb. in Russ. 2. f. 1.			*			Luga, Adsel.	
1.	Pterinea bicarinata	Gold. 119. f. 3.	*					Lindlar (Westphalia).	
2.	— carinata	id. ib. f. 8.	*					ib.	State of New York.
3.	— costata	id. 120. f. 4; Tab. XXXVIII. 3.	*					Ems, Kemmenau.	
4.	— elegans	id. 119. f. 9. an Modiola squamifera? Phil. Geol. Yorks. f. 5. f. 22.			*	*	*	Eifel, Chimay, Villmar, D.; Ratingen, Yorksh., C.	
5.	— elongata	id. ib. f. 5.	*					Ems, Kemmenau.	
6.	— fasciculata	id. 120. f. 5.	*					ib.	ib.
7.	— Goldfusiana	de Kon. (ined.)			*			Chimay.	
8.	— lævis	Gold. 119. f. 1.	*					Kemmenau, Hartz, Lahn near Weilburg.	
9.	— lamellosa	id. 120. f. 12; Tab. XXXVIII. 12. *posteà*, p. 408.	*					Siegen, Kemmenau, Weipperthal, Hartz.	
10.	— lineata	id. 119. f. 6.	*	*	*			Ems, Kemmenau, S., Chimay, Couvin,	
11.	— plana	Gold. 119. f. 4.	*					Ems, Kemmenau. [D.	
12.	— radiata	id. ib. f. 7.			*			Plymouth, Eifel, Iserlohn.	
13.	— spinosa	Phil. pal. fos. 21. f. 81.			*			Woodabay, Newton.	
14.	— trigona	Gold. 120. f. 3.	*					Ems, Kemmenau.	
15.	— ventricosa	id. 119. f. 2; Phil. pal. fos. 21. f. 82.	*	*	*			Iserlohn, Ems, Kemmenau, S.; Petherwin, D.	
16.	— costata	J. Sow.; Tab. XXXVIII. *posteà*, p. 408.	*					Kemmenau.	
1.	Inoceramus acutus	Münst. Beitr. H. 3. 10. f. 4.			*			Schübelhammer.	
2.	— arcuatus	id. ib. 10. f. 5.			*			Geiser.	
3.	— inversus	id. ib. p. 47. Gold. 108. f. 6			*			Baireuth, Gattendorf.	
4.	— obovatus	id. 10. f. 6.			*			Geiser near Presseck.	
5.	— regularis	id. ib. f. 1.			*			Presseck.	
6.	— semiorbicularis	id. ib. f. 2.			*			ib.	
7.	— semistriatus	id. ib. f. 7.			*			ib.	
8.	— trigonus	id. ib. f. 3.			*			ib.	
9.	— vetustus	Min. C. 584. f. 2; Phil. 6. f. 3, 4; (Posidonomya, de Kon.)			*	*	*	Elbersreuth, D.; Regnitzlosau near Hof, Ratingen, Visé, Yorksh., Derbysh., C.	
	Dimyaria.								
1.	Unio carbonarius	Gold. 131. f. 19.					*	Kusel, Lower Palatinate.	
2.	— tellinarius	id. ib. f. 17.					*	Werden, Liège.	
3.	— uniformis	id. ib. f. 20.					*	Kusel.	
4.	— utratus	id. ib. f. 16.					*	Werden.	
1.	Mytilus antiquus?	Gold. p. 168.	*					Altenahr.	
2.	— costatus	Münst. Beitr. H. 3. 11. f. 12.			*			Schübelhammer.	
3.	— Damnoniensis	Phil. pal. fos. 17. f. 61.			*			Newton Bushel.	
4.	— irregularis	Münst. Beitr. H. 3. 12. f. 15.			*			Presseck (Clym. lim.).	
5.	— minimus?	Hœn.			*			Paffrath.	
6.	— obliquus	Münst. Beitr. H. 3. 12. f. 13.			*			Geiser, (Clym. lim.) Presseck.	
7.	— priscus	Gold. 160. f. 13.			*			Eifel.	
8.	— pygmæus	id. 128. f. 6.					*	Ratingen.	
9.	— radiatus	Münst. Beitr. H. 3. 12. f. 16.					*	Schübelhammer (Clym. lim.).	
10.	— substriatus	id. ib. f. 11.			*			ib.	
11.	— subsulcatus	id. 13. f. 14.			*			Elbersreuth (Orth. lim.).	
12.	— veteratus?	Gold. p. 168.					*	Herborn.	
1.	Modiola acuta	Münst. 11. f. 20.			*			Elbersreuth.	
2.	— amygdalina	Phil. pal. fos. 17. f. 62.			*			Petherwin.	
3.	— antiqua	Gold. 13. f. 5. (non id. Sow. Sil. Syst.)	*	*	*			Ems, Nassau, S.; Volkof, Isvosk, D.	
4.	— bilobata	Münst. Beitr. H. 3. 12. f. 18.			*			Elbersreuth (Orth. lim.).	
5.	— cuspidata	de B. Gon. u. Clym. in Schl., Abhandl. 1838. f. 11; Myt. cuspidat. Münst. Beitr. H. 3. 11. f. 10.					*	Silesia, Falckenberg, Presseck, Geiser.	
6.	— scalaris	Phil. pal. fos. 60. f. 62*.			*			Berry Pomeroy.	
7.	— semistriata	Münst. 12. f. 19.			*			Elbersreuth (Orth. lim.).	
8.	— semisulcata	Sow. Sil. Syst. 8. f. 6; Cypricardia id. Phil. pal. fos. 17. f. 57.		*	*			Near Aymestry, S., Petherwin, D.	
9.	— vetusta	Münst. Beitr. 1840. 11. f. 17.			*			Schübelhammer (Clym. lim.).	
1.	Megalodon alutaceus	Gold. 133. f. 2.			*			Paffrath.	
2.	— auriculatus	id. ib. f. 1.			*			ib.	
3.	— carinatus	id. 132. f. 9; Phil. loc. cit. 60. f. 60* *a*, *b*.			*			ib. Newton.	
4.	— cucullatus	Min. C. 568; Gold. 132. f. 8; Phil. loc. cit. 17. f. 60.			*			Newton, Ogwell, Bradley, Paffrath, Sötenich, banks of the Lahn.	

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5.	Megalodon concentricus.	nob. Tab. Nos. XXXVI. 11 *a. antè*, p. 373			*			Paffrath.	
6.	— oblongus	Gold. 133. f. 4.			*			ib. Sötenich.	
7.	— rhomboïdeus	id. ib. f. 3.			*			ib.	
8.	— truncatus	id. 132. f. 10.			*			ib.	
1.	Trigonia? sulcata†	Gold. (Bonn Mus.) nob. Tab. Nos. XXXVII. f. 6., *antè*, p. 374.	*					Ems, Kemmenau.	
1.	Arca carinata	Gold. 160. f. 11.			*			Eifel.	
2.	— concentrica	Münst. Beitr. H. 3. 11. f. 8.			*			Elbersreuth.	
3.	— Michelini	nob. Tab. Nos. XXXVI. 6. *antè*, p. 373			*			Paffrath.	
4.	— prisca	Gold. 160. f. 10.					*	County of Glatz.	
5.	— torulosa	de B. Gon. u. Clym., Abhandl. 1838. f. 12.					*	Falckenberg (ib.).	
1.	Cucullæa amygdalina	Phil. pal. fos. 18. f. 66.			*			Marwood.	
2.	— angusta	Sow. Geol. Trans. vol. v. 53. f. 25; Arca id. Phil. pal. fos. 19. f. 68.			*			ib.	
3.	— antiqua	Sow. Sil. Syst. 3. f. 1 *b*.			*			Horeb Chapel, Felindre, D.	
4.	— depressa	Phil. pal. fos. 19. f. 71. p. 42.			*			Marwood.	
5.	— Hardingii	Sow. Geol. Trans. vol. v. 53. f. 26, 27; Phil. pal. fos. 18, 19. f. 67.			*			ib.	
6.	— ovata	Sow. Sil. Syst. 3. f. 12, *b*. (Nucula id. Phil. pal. fos. 18. f. 65.)			*			Felindre, North and South Devonsh.	South Africa.
7.	— trapezium	id. Geol. Trans. vol. v. 53. f. 24; Phil. ib. 19. f. 70.			*			ib.	
8.	— unilateralis	id. ib. f. 23; id. ib. f. 69.			*			ib.	
1.	Nucula fornicata	Gold. 124. f. 5.	*	*	*			Olpe, S.; Bensberg, Eifel, D.	
2.	— grandæva	id. ib. f. 3.	*					Ems, Nassau, Hartz.	
3.	— latissima	Phil. pal. fos. 58. f. 65*.			*			Pilton.	
4.	— lineata	id. ib. 18. f. 64, α.			*			Baggy Point.	
5.	— id. var. *b*.	id. ib. 64, β.			*			ib.	
6.	— Murchisoni	Gold. 160. f. 12.			*			Eifel.	
7.	— obesa	id. 124. f. 4.	*					Ems, Nassau.	
8.	— obsoleta	id. ib. f. 6.	*					Solingen.	
9.	— plicata	Phil. pal. fos. 18. f. 69.			*			Baggy Point.	
10.	— prisca	Gold. 124. f. 7.	*					Ems, Nassau.	
11.	— id. var. lævis	id. ib.			*			Bensberg.	
12.	— Protei	Münst. Beitr. H. 3. 11. f. 9.			*			Elbersreuth.	
13.	— securiformis	Gold. 124. f. 8.	*					Ems.	
14.	— solenoïdes	id. ib. f. 9.	*					Hartz.	
1.	Isocardia antiqua	id. 140. f. 1.	*					Nassau, Wissenbach.	
2.	— extensa	Münst. Beitr. H. 3. 13. f. 18.			*			Schübelhammer (Clym. lim.).	
3.	— Humboldtii	Gold. 140. f. 2.	*					Nassau, Wissenbach.	
4.	— vetusta	id. 160. f. 14.			*			Eifel.	
1.	Cypricardia cymbæformis.	Sow. Sil. Syst. 3. f. 10; Card. carpomorphum, Dalm., His., Leth. Suec. 19. f. 5.		*	*			Ludlow, East Gottland, S., Felindre.	
2.	— deltoïdea	Phil. pal. fos. 17. f. 59.			*			Petherwin.	
3.	— elongata	nob. Tab. Nos. XXXVI. 14 *a*, *b*. *antè*, p. 374.			*			Villmar.	
4.	— impressa	Sow. Sil. Syst. 5. f. 3; Phil. pal. fos. 17. f. 58.		*	*			Delbury near Ludlow, S.; Baggy Point.	
5.	— rhombea?	Phil. Geol. Yorks. 5. f. 10. *antè*, p. 374			*?	*		Villmar? D.; Yorkshire, Ural, C.	
1.	Cardium aliforme	Min. C. 552. f. 2; Sow. Geol. Trans. vol. v. 56. f. 2; id. de Kon. Recherch. Anim. Foss. Belg. 4. f. 12; Pleurorhynchus id. Phil. id. Pal. fos. 17. f. 51; Gold. 142. f. 1; Conocardium, Bronn; Lychas, Stein.; Bull. Soc. Géol. France, vol. viii. p. 231; Bucardites hystericus, Schlot. 20. f. 1. *antè*, p. 374			*	*		Plymouth, Newton, Eifel, Paffrath, the Hubigenstein (Hartz), Elbersreuth, D.; Bolland, Scarlet, Isle of Man, Tournay, Visé, C.	
2.	— id. var. clathrata	Gold. ib. f. 1 *g*; Tab. Nos. XXXVI. 7 *a*.			*			Paffrath, Eifel.	
3.	— alternans	Münst. Beitr. H. 3. 13. f. 5.			*			Elbersreuth.	
4.	— angulatum	id. Gold. 142. f. 7.			*			ib.	
5.	— arcuatum	id. 13. f. 8.			*			ib.	
6.	— bicarinatum	id. 12. f. 7.			*			ib.	
7.	— Cornucopia	Gold. 143. f. 1; Cardiola interrupta, Sow. Sil. Syst. 8. f. 5.		*	*			Aymestry, Welshpool, S.; Elbersreuth, Prague? St. Sauveur, Feugeurolles, D.	
8.	— costulatum	Gold. 143. f. 4.			*			Elbersreuth, Gattendorf, Prague.	

† We have received this fossil from M. Dannenberg under the name of Trig. sulcata, as given by Goldf. himself, but the name cannot be retained, having already been applied to a different species of Trigonia from the chalk. As our fossil is only a cast of the inside which does not permit a very exact determination, we prefer to give it no new specific name.

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9.	Cardium decussatum.	Münst. Beitr. H. 3. 12. f. 6.			*			Elbersreuth, Gattendorf, Prague.	
10.	— deltoïdeum	id. 13. f. 3.			*			ib.	
11.	— dimidiatum	Gold. 160. f. 16.			*			Eifel.	
12.	— disjunctum	Münst. Beitr. H. iii. 12. f. 18.			*			Elbersreuth.	
13.	— elongatum	Min. C. 82. f. 3; Pleurorhynchus, Phil. Geol. Yorks. 5. f. 28; Conocardium, Bronn, Leth. Geog. 3. f. 9.					*	Ratingen, Visé, Bolland, Derbyshire, Vitegra, Arkangelskoï, rolled in the Volga.	
14.	— Eulimene	Münst. loc. cit. 13. f. 19.			*			Schübelhammer.	
15.	— glabrum	Münst. 12. f. 11.			*			Elbersreuth.	
16.	— gracile	Gold. 142. f. 6.			*			ib.	
17.	— Hibernicum	Min. C. 82. f. 1, 2; id. de Kon. Recher. Anim. Foss. Belg. 4. f. 13.; Pleurorhynchus id. Phil. Geol. Yorks. 5. f. 26; Agassiz, French Transl. Min. Con.			*?	*	*	Chimay, D; Huy, D.; Ratingen, Queen's County, Mendip Hills, Limerick, Namur, Visé, C.	
18.	— incertum	Gold. 141. f. 3.	*					Banks of the Rhine. (Rheinischen Gebirge.)	
19.	— intermedium	id. 143. f. 2. (Cardiola, Münst. Beitr. H. 3. p. 67.)			*			Baireuth.	
20.	— interpunctatum	Münst. 12. f. 10.			*			Elbersreuth.	
21.	— laterale	id. 13. f. 4.			*			Schübelhammer (Clym. lim.).	
22.	— latum	Gold. 143. f. 6.			*			Gattendorf.	
23.	— lineatum	id. 142. f. 4.			*			Elbersreuth.	
24.	— loricatum	id. 141. f. 5.			*			Eifel, Paffrath.	
25.	— Lyellii	nob. Tab. Nos. XXXVI. 8 *a*, *b*. *antè*, p. 375.			*			Villmar.	
26.	— marginatum	Gold. 141. f. 4.	*					Nassau, Kemmenau.	
27.	— Menippe	Münst. Beitr. H. 3. 12. f. 4.			*			Elbersreuth.	
28.	— Mytiloïdes	id. Gold. 142. f. 5.			*			ib.	
29.	— Murchisoni	Münst. Beitr. H. 3. 13. f. 17.			*			ib.	
30.	— nudum	id. ib. 12. f. 2.			*			ib.	
31.	— palmatum	Gold. 143. f. 7. *antè*, p. 374			*			Gattendorf, Presseck, Schübelhammer, Fichtelgebirge, Martenberg (Waldeck), Oberscheld, Adorf, West-[phalia.	Nova Zembla.
32.	33. id. var. *a*, *b*.				*			Oberscheld.	
34.	— paucicostatum	Münst. Beitr. H. 3. 13. f. 2.			*			Elbersreuth.	
35.	— pectunculoïdes	nob. Tab. Nos. XXXVI. 12 *a*. *ante*, p. 375			*			Oberscheld, Waldeck.	
36.	— plicatum	Münst., Gold. 142. f. 9.			*			Elbersreuth, Prague.	
37.	— propinquum	id. Beitr. H. 3. 12. f. 1.			*			ib.	
38.	— quinquecostatum	id. 13. f. 6.			*			ib.	
39.	— semialatum	id. ib. f. 1.			*			ib.	
40.	— semicinctum	id. ib. f. 7.			*			ib.	
41.	— subarquatum	id. 12. f. 3.			*			ib.	
42.	— subgranulatum	id. 13. f. 15; Gold. 143. f. 5.			*			Gattendorf (Clym. lim.).	
43.	— subsimile	id. 12. f. 5.			*			Elbersreuth.	
44.	— tenuistriatum	id. Gold. 143. f. 3.			*			ib. Prague.	
45.	— texturatum	id. Beitr. H. 3. 12. f. 9.			*			ib.	
46.	— triangulum	id. Gold. 142. f. 3.			*			ib.	
47.	— trigonum	id. ib. f. 8			*			ib.	
48.	— tripartitum	id. ib. f. 10.			*			ib.	
49.	— tenuisulcatum	id. H. 3. 13. f. 13.			*			ib.	
50.	— Villmarense	nob. Tab. Nos. XXXVI. 9 *a*. *antè*, p. 375.			*			Villmar.	
51.	— id. var. *a*	nob. Tab. Nos. XXXVI. 10 *a*. *antè*, p. 375			*			ib.	
1.	Pleurorhynchus minax.	Phil. Geol. Yorks. 5. f. 27; Pal. fos. 17. f. 50.			*	*	*	Bradley, Halberton, D.; Bolland, Kildare, Whitewell, Ratingen, C.	
1.	Cardiola articulata	Münst. Beitr. H. 3. 9. f. 2.			*			Gattendorf (Clym. lim.).	
2.	— biplicata	id. ib. p. 69.			*			ib.	
3.	— dichotoma	id. 12. f. 16.			*			Schübelhammer.	
4.	— duplicata	id. 13. f. 20.			*			Gattendorf (Clym. lim.).	
5.	— elegans	id. 12. f. 13.			*			Elbersreuth.	
6.	— sinuosa	id. ib. f. 15.			*			Schübelhammer (Clym. lim.).	
7.	— spurius	id. ib. f. 12.			*			Elbersreuth.	
8.	— subdecussata	id. 13. f. 16.			*			Schübelhammer (Clym. lim.).	
9.	— tegulata	id. 12. f. 14.			*			Elbersreuth.	
1.	Lunulacardium canalifer.	id. 13. f. 11.			*			Schübelhammer (Clym. lim.).	
2.	— excrescens	id. ib. f. 12.			*			ib.	
3.	— ovatum	id. ib. 12. f. 18.			*			Schübelhammer.	
4.	— Partschii	id. ib. f. 17.			*			ib.	

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5.	Lunulacardium procrescens.	Münst. Beitr. H. 3. 12. f. 19.			*			Schübelhammer.	
6.	— pyriforme	id. 13. f. 10.			*			ib.	
7.	— semistriatum	id. ib. f. 9.			*			ib.	
8.	— tetragonum	id. 12. f. 20.			*			Geiser near Presseck (Clym. lim.).	
1.	Pullastra antiqua	Sow. Geol. Trans. vol. v. 53. f. 28.			*			Plymouth, Pilton, Marwood.	
2.	— complanata	Sow. Sil. Syst. 5. f. 7; Phil. pal. fos. 17. f. 56.		*	*			Near Bridgenorth, Shrops., S.; Pilton,	
3.	— elliptica	Phil. pal. fos. 17. f. 54.			*			Petherwin. [D.	
4.	— lævis	Sow. Sil. Syst. 3. f. 1.			*			Felindre.	
1.	Astarte cincta	Gold. 134. f. 5.					*	Ratingen.	
2.	— Neptuni	Münst. Beitr. H. 3. 12. f. 22.			*			Presseck.	
1.	Lucina antiqua	Gold. 146. f. 7. *antè*, p. 376.			*			Eifel, Paffrath.	
2.	— lineata	id. ib. f. 8.			*			ib.	
3.	— Dufrenoyi	nob. Tab. Nos. XXXVII. 2, *a*. *antè*, p. 375.			*			Sötenich.	
4.	— proavia	Gold. 146. f. 6; Tab. Nos. XXXVII. 1, *a*. p. 375.			*			Eifel, Bensberg, Lustheide, &c.	
5.	— rugosa	id. ib. f. 9.			*			ib.	
1.	Tellina obliqua	id. 147. f. 12.	*					Kemmenau.	
1.	Sanguinolaria angustata.	Phil. Geol. Yorks. 5. f. 2; Gold. 159. f. 9.	*	*	*	*		Siebengebirge, S.; Eifel, D.; Peredki, Valdaï, Bolland C.	
2.	— carinata	Gold. 159. f. 8.; aff. Cypric. rhombea, Phil. Geol. York. 5. f. 10.	*					Westerwald.	
3.	— compressa	id. ib. f. 16.			*			Eifel.	
4.	— dorsata	id. ib. f. 17.	*	*	*			Altenahr, S., Eifel, D.	
5.	— gibbosa	id. ib. f. 10. an id.? Min. C. 548. f. 3.	*					Altenahr, S.; Ireland, C.	
6.	— lamellosa	id. ib. f. 12.			*			Eifel.	
7.	— lævigata	id. ib. f. 14.			*			ib.	
8.	— lyrata	Phil. pal. fos. 58. f. 53*, *a*, *b*.			*			Pilton.	
9.	— obovata	Münst. Beitr. H. 3. 12. f. 29.			*			Elbersreuth.	
10.	— phaseolina	Gold. 159. f. 15.			*			Eifel.	
11.	— striata	id. ib. f. 19.					*	Regnitzlosau.	
12.	— pygmæa	id. ib. f. 20.			*			Schübelhammer.	
13.	— soleniformis	id. ib. f. 7.	*					Altenahr, Siebengebirge.	
14.	— sulcata	Phil. 5. f. 5; Gold. 159. f. 11; S. concentrica, Hiatella, Flem. Brit. Anim. p. 462.			*	*		ib. Moscow, Peredki, Northumb., C.	
15.	— sulcata	Münst. Beitr. H. 3. 12. f. 26; Phil. pal. fos. 17. f. 52, an Psammobia rigida, Sow. Sil. Syst.? 8. f. 3.		*?	*	*		Aymestry? S.; Petherwin, Schübelhammer, D.; Combe, C.	
16.	— tellinaria	Gold. 159. f. 18.			*			Eifel.	
17.	— trigona	Münst. 12. f. 28.			*			Elbersreuth.	
18.	— truncata	Gold. 159. f. 13.			*			Eifel.	
19.	— undata	Münst. 12. f. 27; Cypric. id. Sow. Sil. Syst. 5. f. 4.		*	*			Near Aymestry, S.; Schübelhammer,	
20.	— (indet.)	*antè*, p. 376.			*			Villmar. [D.	
1.	Corbula Hennahii	Sow. Geol. Trans. vol. v. 56. f. 1.			*			Plymouth.	
1.	Erycina glabra	Münst. Beitr. H. 3. 12. f. 23.			*			Elbersreuth (Orth. lim.).	
2.	— pygmæa	id. ib. f. 25.			*			ib.	
3.	— striata	id. ib. f. 24.			*			ib.	
1.	Pholadomya Munsteri	nob. Tab. Nos. XXXVII. 3, 3 *a*, 3 *b*. *antè*, p. 376.			*			Eifel, Bensberg.	
2.	— radiata	Gold. 155. f. 1.			*			ib.	
1.	Lutraria prisca	Goldf. Pet. Germ. 153. f. 9.			*			Eifel.	
1.	Solen Lustheidii	nob. Tab. Nos. XXXVII. 4, 4 *a*, 4 *b*. *antè*, p. 376.			*			Lustheide.	
2.	— pelagicus	Gold. 159. f. 2; Tab. Nos. XXXVII. 5, 5 *a*, 5 *b*. p. 376.			*			Eifel.	
3.	— vetustus	id. ib. f. 3.			*			ib.	
	Annelides.								
1.	Serpula ammonia	Gold. 67. f. 2.			*			Gerolstein.	
2.	— epithonia	id. ib. f. 1.			*			Bensberg.	
3.	— Omphalotes	id. ib. f. 3; Spirorbis Hœninghausi, Stein. Mém. Soc. Géol. France, t. i. p. 358.			*			ib. Eifel, Ferques, Lake Ilmen, Volkof, Voroneje.	
1.	Serpularia bicrenata	Münst. Beitr. H. 3. 9. f. 15.			*			Elbersreuth (Orth. lim.).	
2.	— crenata	id. ib. f. 14.			*			ib.	
	Radiaria.								
1.	Cidarites (fragment).	de Kon.			*			Chimay. Fragments not uncommon in Carb. Limestone in Belgium, Scotland, England, and abundant in the same beds in Russia.	

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1.	Cyathocrinites dubius	Münst. Beitr. H. 3. 9. f. 10	...	...	*	...	...	Schübelhammer, Gattendorf.	
2.	— ? ellipticus ?	Phil. pal. fos. 16. f. 49	...	...	*	...	...	Petherwin.	
3.	— geometricus	Gold. 58. f. 5; Phil. pal. fos. 60. f. 41*	...	...	*	...	...	Newton, Eifel.	
4.	— macrodactylus	Phil. pal. fos. 15. f. 41	...	...	*	...	...	Brushfort, Pilton.	
5.	— ? megastylus ?	id. ib. 16. f. 47.	...	...	*	*	...	Whitesand Bay, D., Whitewell, C.	
6.	— ? nodulosus ?	id. ib. f. 46	...	...	*	...	...	Torquay.	
7.	— pinnatus	Gold. 58. f. 7; Phil. pal. fos. 16. f. 45.	...	*	*	*	...	West Gottland, S.; Mudstone Bay, Eifel, Goslar, D.; Ashburton, C.	State of New York.
8.	— rugosus	id. 59. f. 1; His. Leth. Suec. 25. f. 3; de B. Beit. Geb. Russl. p. 62.	...	*	*	*	...	Wenlock, Dudley, Oeland, Gottland, Dalecarlia, S.; Eifel, D.; Valdaï, C.	
9.	— teres	Münst. Beitr. H. 3. 9. f. 9.	...	...	*	...	...	Schübelhammer.	
10.	— tuberculatus	Mill., Gold. 58. f. 6; Sil. Syst. 18. f. 6, 7; Encrin. moniliformis, Fisch.; Oryc. Govern. Moscou, 40. f. 1. 4–6, 41. f. 1–4.	*	...	...	...	*	Dudley, banks of Rhine, S.; South Ireland, Valdaï, Moscow, C.	
11.	— variabilis	Phil. pal. fos. 16. f. 48	...	...	*	...	...	Pilton.	
1.	Rhodocrinites canaliculatus.	Gold. 60. f. 6	...	...	*	...	...	Eifel.	
2.	— crenatus	id. 64. f. 3.	...	...	*	...	...	ib.	
3.	— gyratus	id. 60. f. 4.	...	...	*	...	...	ib.	
4.	— quinquepartitus	id. ib. f. 5.	...	...	*	...	...	ib.	
5.	— verus	Miller, id. ib. f. 3.	...	*	*	*	...	Dudley, S.; Eifel, Volkof, Tchudovo, D.; Mendip Hills, Bristol, Donetz, C.	
1.	Melocrinites lævis	Gold. 60. f. 2	...	...	*	*?	...	Eifel, Baireuth, D.; Regnitzlosau, C.	
2.	— fornicatus	id. Nov. Act. Acad. 31. f. 2.	...	...	*	...	...	ib.	
3.	— gibbosus	id. 64. f. 2.	...	...	*	...	...	ib.	
4.	— hieroglyphicus	id. 60. f. 1.	...	...	*	*	*	ib., D.; Stolberg, C.	
5.	— pyramidalis	id. Nov. Act. Acad. 31. f. 1.	...	...	*	...	...	ib.	
6.	— verrucosus	id. ib. f. 3.	...	...	*	...	...	ib.	
1.	Gastrocoma antiqua	id. ib. 32. f. 5.	...	...	*	...	...	ib.	
1.	Actinocrinites cingulatus.	id. 59. f. 7.	...	...	*	...	...	ib.	
2.	— Gilbertsonii	Melocrin. Amphora, Gold. Nov. Act. Acad. 31. f. 4.	...	...	*?	*	...	Eifel ? D.; Yorkshire, Bolland, C.	
3.	— lævis	Gold. Nov. Act. Acad. f. 3.	...	...	*	*	*	ib., D., Ratingen, C.	
4.	— moniliferus	id. ib. f. 10	...	...	*	...	...	ib.	
5.	— muricatus	id. ib. f. 8.	...	...	*	...	...	ib.	
6.	— nodulosus	id. ib. f. 9.	...	...	*	...	...	ib.	
7.	— striatus	Münst. Beitr. H. 3. 9. f. 11	...	...	*	...	...	Geiser, near Hof.	
8.	— tenuistriatus	Phil. pal. fos. 16. f. 44	...	...	*	...	...	Linton, Pilton, Plymouth.	
9.	— triacontadactylus	Mill., Phil. pal. fos. 16. f. 43.	...	...	*	*	...	Newton, Eifel ? D.; Yorkshire, Bristol, South Ireland, Mendip Hills, C.	
1.	Platycrinites decagonus.	Gold. Act. Acad. Cæs. v. xix. p. 19	...	...	*	...	...	Eifel.	
2.	— depressus	id. 58. f. 1.	...	...	*	*	*	ib., D., Ratingen, C.	
3.	— hieroglyphicus	id. Nov. Act. Acad. 31. f. 9	...	...	*	...	...	ib.	
4.	— interscapularis	Phil. pal. fos. 14. f. 39	...	...	*	...	...	Plymouth, Newton.	
5.	— ornatus	Gold. Nov. Act. Acad.	...	...	*	...	...	Eifel.	
6.	— pentangularis	Mill., Phil. pal. fos. 60. f. 42*, p. 135.	...	...	*	*	...	Newton, D.; Bristol, Tournay, C.	
7.	— tabulatus	Gold. Nov. Act. Acad.	...	...	*	...	...	Eifel.	
8.	— tuberculatus	Mill., Phil. 3. f. 17; id. Pal. fos. 60. f. 39*	...	...	*	*	...	Newton, D.; Bristol, Bolland, Tournay, C.	
9.	— ventricosus	Gold. 58. f. 4	...	...	*	...	...	Eifel.	
1.	Adelocrinites Hystrix.	Phil. pal. fos. 16. f. 42	...	...	*	...	...	Brushford.	
1.	Pentremites ovalis	Gold. 50. f. 1; Phil. pal. fos. 14. f. 40.	...	...	*	*	*	ib., D., Ratingen.	State of Tennessee.
1.	Sphæronites tessellatus.	Phil. pal. fos. 59. f. 49**. p. 135.	...	...	*	...	...	South Devonshire.	
1.	Eucalyptocrinites rosaceus.	Gold. 64. f. 7	...	*	*	...	...	Gottland, S., Eifel, D.	
1.	Cupressocrinites crassus.	id. 64. f. 4.	...	...	*	...	...	Eifel.	
2.	— abbreviatus	id. Nov. Act. Acad. 30. f. 4	...	...	*	...	...	ib. Villmar.	
3.	— elongatus	id. ib. f. 2.	...	...	*	...	...	ib.	
4.	— gracilis	id. 64. f. 5.	...	...	*	...	...	ib.	
5.	— tesseratus	id. 59. f. 11.	...	...	*	...	...	ib.	
6.	— tetragonus	id. Nov. Act. Acad. 30. f. 3	...	...	*	...	...	ib.	Perry County, State of Tennessee.
1.	Eugeniacrinites mespiliformis.	id. 64. f. 6; Haplocrinites sphæroïdeus, Stein. Bull., Soc. Géol. de France, &c. t. viii. p. 232. f. 19.	...	...	*	...	...	ib.	

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2.	Eugeniacrinites sessilis.	Münst. Beitr. H. 3. 1840. 9. f. 7.	...	...	*	...	...	Schübelhammer.	
1.	Pentacrinites priscus.	Gold. 53. f. 7	...	...	*	...	...	Eifel.	
1.	Triacrinus pyriformis	Münst. Beitr. H. 1. 1839. 1. f. 4	...	...	*	...	...	Schübelhammer (Clym. lim.).	
2.	— granulatus	id. H. 1. 9. f. 7	...	...	*	...	...	ib.	
1.	Asterocrinus Murchisoni.	id. ib. 16. f. 7	...	...	*	...	...	Elbersreuth (Orth. lim.).	
1.	Scyphocrinites elegans.	id. Beitr. H. 3. 1840. 9. f. 8.	...	...	*	...	...	ib. Bohemia.	
1.	Ctenocrinus typus	Bronn, N. Jahrb. 1840. p. 542; Tab. Nos. XXXVII. 7. *antè*, p. 377.	*	...	...	...	...	Ems, Haüsling, Nassau.	
1.	Halocrinites pyramidalis.	id. ib. t. ix. p. 295. 6; an Cupressocrinites crassus varietas?	...	...	*	...	...	ib.	
	Foraminifera.								
1.	Indeterm. species	Phil. pal. fos. p. 153	...	...	*	...	...	Cannington Park (North Devon), and South Devon.	
	Polyparia.								
1.	Amplexus tortuosus	Phil. pal. fos. 3. f. 8.	...	...	*	*	...	Petherwin, Plymouth, Torquay, D.; Clane, Kildare, C.	
1.	Caunopora ramosa	Phil. pal. fos. 8. f. 22; Lonsd. Geol. Trans. vol. v. pp. 703, 737, 738.	...	...	*	...	...	Chudleigh, Babbacombe, Eifel, Elbersfeld, Hagen, Schwelm.	Ural, neighbourhood of Bogoslofsk.
1.	Alveolites reticulatus.	Stein. Mém. Soc. Géol. France, t. i. 20. f. 5.	...	...	*	...	...	Eifel.	
1.	Criserpia Michelini	Milne Edw. Dict. des Sc. Nat. Suppl.	...	...	*	...	...	ib. Néhou.	
1.	Aulopora conglomerata.	Gold. 29. f. 4; Lonsd. Sil. Syst. 15. f. 9.	...	*	*	...	...	Wenlock limestone, S.; Bensberg, Eifel, Refrath, Ferques, D.	
2.	— consimilis	Lonsd. Sil. Syst. 15. f. 7.	...	*	*	...	...	Wenlock, S.; Eifel, Refrath, Ferques, D.	
3.	— serpens	Gold. 29. f. 1; Lonsd. Sil. Syst. 15. f. 5; Alecto, Stein. loc. cit. suprà, 20. f. 9.	...	*	*	...	...	Gottland, Dudley, &c., S.; ib. ib. ib. Bensberg, Néhou, Voroneje, D.	Perry County.
4.	— spicata	Gold. ib. f. 3.	...	...	*	...	...	Eifel, Refrath, Bensberg.	
5.	— tubæformis	id. ib. f. 2; Alecto, Stein. loc. cit. suprà, p. 341.	...	*	*	...	...	Wenlock lim., S.; Ferques, Eifel, Refrath, D.	
1.	Favosites alveolaris	de Blainv., Man. d'Act. p. 402; Milne Ed., 2nd edit. Lamk. Anim. sans Vert. t. ii. p. 320; Lonsd. Sil. Syst. 15 bis. f. 1, 2; Fav. prismaticus, Stein. loc. cit. suprà, p. 335; Calamopora alveolaris, Gold. 26. f. 1.	...	*	*	...	...	Aymestry, Wenlock, Llandovery, Revel, S.; Ferques, Eifel, D.	Ural, Perry County, State of Tennessee.
2.	— basaltica	de Blainv., loc. cit., reunited to Fav. Gothlandica by Lonsd. Sil. Syst. p. 682; Calamopora, id. Gold. 26. f. 4; His. Leth. Suec. 27. f. 5.	...	*	*	...	...	Gottland, S.; Eifel, D.	Lake Erie, Drummond, S.; States of New York and Tennessee.
3.	— fibrosa	ib. Lonsd. Sil. Syst. 15 bis. f. 6; Phil. pal. fos. 9. f. 25; Microporus, Stein. loc. cit. suprà, p. 337; Fav. petropolitana, Pander, Beitr. Geogn. Russ. p. 105; Calamopora, id. Gold. 28. f. 3, 4.	...	*	*	...	...	St. Petersburg, S.; Eifel, Bensberg, Fowey, Hillsborough, Combe Martin, Darlington, Sharkham, D.	Kentucky, State of New York.
4.	— Gothlandica	id. ib. Lam. Anim. sans Vert. t. ii.; Lonsd. Sil. Syst. 15 bis. f. 3, 4; Phil. pal. fos. 7. f. 21; F. prismaticus, Stein. loc. cit. suprà; Sarcinula angularis, Flem. Brit. Anim. p. 308; His. 27. f. 4; Calamopora, Gold. 26. f. 3.	...	*	*	...	...	Aymestry, Wenlock, Tortworth, Gottland, Dalecarlia, Lithuania, Dalmatia, St. Petersburg, Revel, Island of Dago, S.; Plymouth, Sharkham, Babbacombe, Eifel, Refrath, Paffrath, Néhou, Izé, Voroneje, D.	Ural, Lake Erie, Drummond, S.; Nashville, Missouri, Kentucky, State of the Ohio, New Holland.
5.	— ? infundibuliformis	Calamopora, id. Gold. 27. f. 1.	...	...	*	...	...	Eifel, Bensberg.	Perry County, Kentucky.
6.	— polymorpha	Lonsd. Sil. Syst. 15 bis. f. 2; Phil. pal. fos. 8. f. 20; Thamnopora, Stein. loc. cit. suprà, p. 337; Calamopora, Gold. 27. f. 2, 3, 4; His. 27. f. 6; Alveolites reticulata, de Blainv. Man. d'Actin. p. 405.	...	*	*	...	...	Steinlacke near Weilburg, Lahn near Villmar, Goslar, Ludlow, Esthonia, S.; Eifel, Bensberg, Newton, Barton, Torquay, Combe Martin, Babbacombe, Plymouth; and Chimay, Couvin, Chaudfontaine, Paffrath, Lustheide, Langenaubach, D.	Most common in the Ural, State of New York.

No. of Species.	Genera and Species.	Authors and References. The numerals refer to Species described and figured in this Memoir.	Sil. Sp. in Rhen. Prov.	Dev. & Sil. Sp.	Devonian Sp.	Dev. & Carb. Sp.	Carb. Sp.	Localities in Europe.	Elsewhere.
7.	Favosites Spongites..	Lonsd. Sil. Syst. 15 bis. f. 8; Phil. pal. fos. 8. f. 23; Alveol. suborbicularis, Lam. loc. cit. suprà, p. 286; Gold. 28. f. 1, 2; His. 27. f. 7.	.....	*	*	...	...	Dollindorf, Voroneje, Dudley, S.; Wenlock, Sweden, Plymouth, Newton, Babbacombe, Ferques, Chimay, Couvin, Chaudfontaine, Eifel, Bensberg, Paffrath, Lustheide, D.	Drummond, W.
1.	Syringopora cæspitosa.	Gold. 25. f. 9; Lonsd. Sil. Syst. 15 bis. f. 10.	.....	*	*	...	...	Wenlock, S.; Paffrath, D.	
2.	— filiformis	id. 38. f. 16; Lonsd. Sil. Syst. 15 bis. f. 12...	*	...	...	...	...	Gröningen (Diluv.), Ludlow and Wenlock rocks.	
3.	— ramulosa	id. 25. f. 7; Phil. Geol. Yorks. Part 2. 2. f. 2.	*	...	...	...	*	Limburg, S.; Mendip Hills, Olpe, Visé, Coalbrook Dale, Bolland, Kirby, Moscow, Vitegra, Valdaï, C.	Ural.
4.	— reticulata	id. ib. f. 8; His. 27. f. 2; Lonsd. Sil. Syst. 15 bis. f. 10; Phil. Geol. Yorks. Part 2. p. 202; Harmodites radians, Fisch., Oryc. Govern. Moscou, p. 161. 37. f. 6; Bronn, Leth. Geogn. p. 51.	.....	*	*	*	*	Wenlock, Gottland, Sweden, S.; Chimay, D.; Olpe, Ashford, Derbyshire, Moscow, Valdaï, C.	State of the Ohio.
5.	— verticillata.....	id. ib. f. 6.	.....	*	*	...	...	Chimay.	Drummond, S.; States of New York &Tennessee.
1.	Catenipora escharoïdes.	Lam., Gold. 25. f. 4; His. 26. f. 9; Lonsd. Sil. Syst. 15 bis. f. 14; Halysites, Fisch., Oryc. Gov. Mosc. 38. f. 3. p. 164; Bronn, Leth. Geogn. p. 52.	.....	*	*?	...	...	Gottland, Dago, Aymestry, Wenlock, Lickey, S.; Eifel (rarissima), D.? Diluv. of Vilna.	Drummond, S.; States of the Ohio and New York.
2.	— labyrinthica	Gold. 25. f. 5.....	*	...	...	...	...	Gröningen, Gottland? Island of Dago, S.; Diluv. of Vilna.	Drummond, S.; State of New York, Perry and Davidson County.
1.	Porites pyriformis	Ehr., Lonsd. Sil. Syst. 16. f. 2; Astræa porosa, Gold. 21. f. 7; His. Leth. Suec. 28. f. 2; Heliopora pyriformis, de Blainv. Man. d' Actinol. p. 392; id. interstincta, Bronn, loc. cit. suprà, 5. f. 4; Phil. pal. fos. 7. f. 19.	*	*	*	...	...	Banks of the Lahn, Steinlacke near Weilburg, Aymestry, Wenlock Edge, Marloes Bay, Island of Dago, S.; Plymouth, Torquay, Newton, Ogwell, Eifel, Bensberg, Refrath, D.	Ural, State of Tennessee.
1.	Coscinopora placenta	Gold. 9. f. 18; Lonsd. Geol. Trans. vol. v. 58. f. 5; Caunopora id. Phil. pal. fos. 10. f. 29.	.....	...	*	...	...	Plymouth, Ogwell, Newton Bushel, Eifel.	
1.	Columnaria stellaris..	Stein. Mém. Soc. Géol. Fr. p. 343.....	.....	...	*	...	...	Eifel.	
1.	Astræa ananas.....	Lam., de Blainv., loc. cit. suprà, p. 369; Lonsd. Sil. Syst. 16. f. 6; His. 28. f. 1; Cyathophyllum id. Gold. 19. f. 4.	.....	*	*	...	...	Wenlock, Gottland, Dalecarlia, S.; Ferques, Chaudfontaine, Eifel, Refrath, D.	
2.	— helianthoïdes	Gold. 20. f. 2, 21. f. 1; Astræa id. de Blainv., loc. cit. suprà, p. 375; Lonsd. Geol. Soc. vol. v. pp. 703, 737; Strombodes id. Phil. pal. fos. 5. f. 13; Monticularia areolata, Stein. Mém. Soc. Géol. Fr. t. 1. 20. f. 10.	.....	*	*	...	...	Oberbicht, Plymouth, Babbacombe, Sharkham Point, Ogwell, Torquay, Chaudfontaine, Eifel.	Lake Huron, States of New York and Tennessee.
3.	— Hennahii	Lonsd. Geol. Trans. vol. v. 58. f. 3.....	.....	...	*	...	...	Plymouth, Barton, Newton.	
4.	— intercellulosa	Phil. pal. fos. 6. f. 17.	.....	...	*	...	...	Torquay.	
5.	— pentagona	de Blainv., loc. cit. suprà, p. 375; Lonsd. Geol. Trans. vol. v. 58. f. 1; id. Phil. pal. fos. 6. f. 15; Gold. 19. f. 3; Cyathophyl. id.	.....	...	*	...	...	Plymouth, Ogwell, Torquay, Chaudfontaine, Couvin, Namur?	
1.	Strombodes vermicularis.	Lonsd. Geol. Trans. vol. v. 58. f. 7; Cyathophyllum id. Gold. 17. f. 4; His., Phil. pal. fos. 7. f. 14.	.....	*	*	...	...	Gottland, S.; Plymouth, Ogwell, Newton, Ferques, Eifel, D.	States of New York and Tennessee.
1.	Petraïa celtica	Lonsd. Geol. 58. f. 6; Turbinolia, Lamour.; Turbinolopsis id. Phil. pal. fos. 1. f. 1.	.....	...	*	...	...	Dinas Cove, Padstow, Berry Pomeroy, Cornwall Bay, Petherwin, Brushford, Kerliver near Le Faou (Bretagne), Drolshagen, D.; Combe, C.	
2.	— decussata	Münst. Beitr. 1839. 3. f. 1.	.....	...	*	...	...	Elbersreuth.	
3.	— Kochii.....	id. ib. f. 5.	.....	...	*	...	...	ib.	
4.	— radiata	id. ib. f. 4.	.....	...	*	...	...	ib.	
5.	— semistriata.....	id. ib. f. 2.	.....	...	*	...	...	ib.	
6.	— tenuicostata	id. ib. f. 3.	.....	...	*	...	...	ib. Schübelhammer.	
1.	Cyathophyllum angustum.	Lonsd. Sil. Syst. 16. f. 9.....	.....	*	*?	...	...	Lickey, S.; Eifel, D.	

No. of species.	Genera and Species.	Authors and References. The numerals refer to Species described and figured in this Memoir.	Sil. Sp. in Rhen. Prov.	Dev. & Sil. Sp.	Devonian Sp.	Dev. & Carb. Sp.	Carb. Sp.	Localities in Europe.	Elsewhere.
2.	Cyathophyllum Ceratites.	Gold. 17. f. 2; His. 28. f. 15.	...	*	*	...	...	Gottland, East Gottland, S.; Chimay, Couvin, Eifel, Bensberg, Oberscheld, D.	Ural, States of the Ohio, New York, &Tennessee.
3.	— cæspitosum	id. 19. f. 2; Lonsd. Sil. Syst. 16. f. 10; Phil. pal. fos. 3. f. 10; Lonsd. Dev. Syst. 58. f. 8; Caryophyllia, Stein. loc. cit. suprà, p. 342.	...	*	*	...	...	Wenlock, S.; Plymouth, Torquay, Ogwell, Ilfracombe, Combe Martin, Lee Quarry, N. Devon, &c.; Ferques, Chimay, Eifel, Bensberg, Refrath, Paffrath, Langenaubach, D.	Ural.
4.	— dianthus	Gold. 15. f. 13; Lonsd. Sil. Syst. 16. f. 12; Caryophyllia truncata, His. 28. f. 14.	...	*	*	...	...	Wenlock Edge, Gottland, S.; Eifel, D.	
5.	— hexagonum	id. 19. f. 5, 20. f. 1.	...	...	*	...	...	Eifel, Bensberg, Refrath.	
6.	— excentricum	id. 16. f. 4.	...	...	...	...	*	Ratingen.	State of Tennessee.
7.	— explanatum	id. ib. f. 5.	...	...	*	...	...	Bensberg.	
8.	— flexuosum	id. 17. f. 3; His. 29. f. 3.	...	*	*	...	...	Lahn near Villmar, Gottland, S.; Eifel, Bensberg, D.	
9.	— hypocrateriforme	id. 17. f. 1.	...	...	*	...	...	Eifel, Bensberg.	
10.	— lamellosum	id. 18. f. 3.	...	...	*	...	...	ib. ib. Refrath.	
11.	— lituoïdes?	Münst. Beitr. H. 3. 9. f. 13.	...	...	*	...	...	Geiser (Clym. lim.).	
12.	— marginatum	Gold. 16. f. 3.	...	...	*	...	...	Bensberg.	
13.	— placentiforme	id. 18. f. 4.	...	...	*	...	...	Couvin, Eifel, Bensberg.	
14.	— priscum	Münst. Beitr. H. 3. 9. f. 12.	...	...	*	...	...	Schübelhammer (Clym. lim.).	
15.	— quadrigeminum	Gold. 18. f. 6, 19. f. 1; Lonsd. Geol. Trans. vol. v. p. 703; Columnaria sulcata, Gold. 24. f. 9; Cyathoph. basaltiforme, Phil. Geol. Yorks., Part 2. 2. f. 21, 22; Manon favosum, Gold. 1. f. 11.	...	...	*	*	...	Eifel, Bensberg, Refrath, Paffrath, Chaudfontaine, D.; Yorkshire, Vereïa, Miatchkova, C.	State of New York, Nashville (Tennessee).
16.	— radicans	id. 16. f. 2.	...	...	*	...	...	Ferques, Eifel.	
17.	— secundum	id. 18. f. 2.	...	...	*	...	...	Eifel, Bensberg.	Tennessee.
18.	— turbinatum	id. 16. f. 8; Lonsd. Geol. Trans. vol. v. pp. 703. 737; Phil. pal. fos. 7. f. 9; His. Leth. Suec. 29. f. 1.	...	*	*	...	...	Wenlock, Prolimore Well, Shropsh., &c., Gottland, West Gottland, S.; Plymouth, Ferques, Eifel, Bensberg,	State of New York.
1.	Cystiphyllum cylindricum.	Lonsd. Sil. Syst. 16 bis. f. 3.	...	*	*	...	...	Wenlock, S.; Eifel, D. [D.	
2.	— Damnoniense	id. Geol. Trans. vol. v. 58. f. 11; Phil. pal. fos. 4. f. 11.	...	...	*	...	...	Plymouth, Ogwell, Newton, &c.	
3.	— Siluriense	id. Sil. Syst. 16 bis. f. 1, 2; Cyathophyl. vesiculosum, Gold. 17. f. 5, 18. f. 1.	...	*	*	...	...	Wenlock, Dudley, S; Couvin, Eifel, D.	
4.	— vesiculosum	Phil. pal. fos. 4. f. 12. (referred to the Cyath. id. Gold., although distinct from the Cyst. Siluriense, Lonsd.)	...	...	*	...	...	Babbacombe, Eifel.	
1.	Turbinolia calycularis	Stein. p. 344.	...	...	*	...	...	Eifel.	
2.	— corniculata	id. ib.	...	...	*	...	...	ib.	
1.	Anthophyllum bicostatum.	Gold. 13. f. 12. Probably a Cyathophyllum with the cortex removed, as stated by M. Steininger.	...	...	*	...	...	Heisterstein in the Eifel.	
1.	Caryophyllia flexuosa	Lam., Lonsd. Sil. Syst. 16. f. 7.	...	*	*	...	...	Malvern, banks of the Baltic, S.; Eifel,	
1.	Lithodendron cæspitosum.	Gold. 13. f. 4	...	...	*	...	...	Bensberg. [D.	
1.	Turbinolopsis pluriradialis.	Phil. pal. fos. 2. f. 5	...	...	*	...	...	Brushford, Linton.	
2.	— id. var *b*.	id. ib. 2. f. 5 β.	...	...	*	...	...	ib. ib. Fowey harbour.	
1.	Hemitrypa oculata	id. ib. 13. f. 38.	...	...	*	...	...	Barton.	
1.	Limaria clathrata	Stein., Lonsd. Sil. Syst. 16 bis. f. 7.	...	*	*	...	...	Dudley, S.; Eifel, D.	
2.	— fruticosa	id. Lonsd. ib. 16 bis. f. 8.	...	*	*	...	...	ib. S.; Eifel, D.	
1.	Ceriopora affinis	Gold. 64. f. 11.	...	...	*	...	...	ib.	
2.	— granulosa	id. ib. f. 13; Lonsd. Sil. Syst. 15. f. 29.	...	*	*	...	...	Dudley, S.; ib., D.	
3.	— oculata	id. ib. f. 14.	...	...	*	...	...	Eifel.	
4.	— punctata	id. ib. f. 12.	...	...	*	...	...	ib.	
5.	— verrucosa	id. 10. f. 6; Phil. Geol. Yorks. Part 2. p. 200.	...	...	*	*	...	Bensberg, D.; Florence Court, C.	
1.	Eschara dubia	Stein. p. 339.	...	...	*	...	...	Eifel.	
1.	Gorgonia assimilis	Lonsd. Sil. Syst. 15. f. 27.	...	*	*	...	...	Wenlock, Dudley, S.; Eifel, D.	
2.	— infundibuliformis.	Gold. 10. f. 1; Escharites retiformis, Schlot. Petref. p. 342; Retepora, Schröt. Einleit. 9. f. 2. p. 480. an Retep. id. Lonsd. Sil. Syst. 15. f. 24.	*	...	...	...	...	Ems, Elbersfeld, Lindlar, Wipperfurth, Gimborn, Kemmenau, Heigerselbach.	

No. of Species.	Genera and Species.	Authors and References. The numerals refer to Species described and figured in this Memoir.	Sil. Sp. in Rhen. Prov.	Dev. & Sil. Sp.	Devonian Sp.	Dev. & Carb. Sp.	Carb. Sp.	Localities in Europe.	Elsewhere.
3.	Gorgonia ripisteria...	Gold. 7. f. 2; Phil. pal. fos. 11. f. 30.	*	*	*	*	...	Kemmenau, S.; Mudstone Bay, D.; Tournay, C.	
1.	Ptylodictya lanceolata	Lonsd. Sil. Syst. 15. f. 11; Flustra id. Gold. 37. f. 2. His. 29. f. 10.	*	...	...	...	...	Wenlock, Gottland, Esthonia, Dil. of Groningen.	
1.	Flustra? radiata	Stein. 20. f. 3.	...	...	*	...	...	Eifel.	
1.	Glauconome bipinnata.	Phil. pal. fos. 11. f. 33.....	...	...	*	...	...	Croyde, Pilton, Brushford.	
2.	— disticha	Gold. 64. f. 15; Lonsd. Sil. Syst. 15. f. 12...	...	*	*	...	...	Wenlock, Dudley, S., Eifel, D.	
1.	Fenestella antiqua ...	var. β, γ, Lonsd. Sil. Syst. 15. f. 16; id. Geol. Trans. vol. v. 58. f. 2; Phil. pal. fos. 12. f. 35; Gorgonia id. Gold. 36. f. 3.	...	*	*	...	...	Dudley, S.; Plymouth, Fowey, Pilton, Brushford, Petherwin, Barton, D.	
2.	— id. var. α.....	.....	...	...	*	...	...	Linton, Watersmeet, Petherwin, &c.	
3.	— id. var. δ.	.....	...	...	*	...	...	Petherwin.	
4.	— arthritica	Phil. pal. fos. 12. f. 36.	...	...	*	...	...	Torquay, Hope, West Haggington.	
5.	— laxa	Phil. Geol. Yorks. 1. f. 26, 30; Fenestella id. Phil. pal. fos. 12. f. 34.	...	...	*	*	...	Petherwin, Croyde, D.; Whitewell, C.; Kildare, Valdaï.	
6.	— prisca	Lonsd. Sil. Syst. 15. f. 15 & 18; Retepora id. Gold. 36. f. 19; Phil. pal. fos. 13. f. 37.	...	*	*	...	...	Wenlock, S.; Plymouth, Barton, Eifel, D.	
1.	Retepora antiqua	Gold. 9. f. 10.....	...	...	*	...	...	Chimay, Eifel.	State of the Ohio.
2.	— flabellulum	Stein. p. 340.	...	...	*	...	...	Eifel.	
3.	— pertusa?.....	Stein. loc. cit. suprà, 20. f. 8. p. 340.....	...	...	*	...	...	ib.	
1.	Discopora antiqua ...	Milne Ed., 2nd edit. Lamk. t. ii. p. 253; Lonsd. Sil. Syst. 15. f. 21; Cellepora id. Gold. 9. f. 8.	...	...	*	...	...	Wenlock, Dudley, S., Eifel, D.	
1.	Cellepora favosa	Gold. 64. f. 16; Discopora, Lonsd. Sil. Syst. 15. f. 22.	...	*	*	...	...	Wenlock, S.; Eifel, D.	
2.	— tenella	Stein. Mém. Soc. Géol. France, p. 333.	...	...	*	...	...	Eifel.	
1.	Millepora exigua.....	id. 342.	...	...	*	...	...	ib.	
2.	— gracilis	Phil. pal. fos. 11. f. 31.....	...	...	*	...	...	Croyde, Pilton.	
3.	— similis	id. ib. f. 32.	...	...	*	...	...	Torquay, Cannington Park.	
1.	Stromatopora concentrica.	Gold. 8. f. 5; de Blainv. Man. d'Act. 70. f. 1; Lonsd. Sil. Syst. 15. f. 31; Phil. pal. fos. 10. f. 28; Spongia undulata, Stein. loc. cit. suprà, p. 347.	...	*	*	...	...	Wenlock, Dudley, S.; Chudleigh, Torquay, banks of the Lahn, Langenaubach, Schwelm, D.	Most common in the Ural, Latchak (Siberia), Middle Tennessee.
2.	— polymorpha	Gold. 10. f. 6, 64. f. 8; Lonsd. Geol. Trans. vol. v. pp. 703. 737; Phil. pal. fos. 10. f. 27.	...	*	*	...	...	Island of Dago, S.; Eifel, Hagen, Paffrath, Schwelm, Mettmann, Lahn, Elbersfeld, Chudleigh, Darlington, D.	
1.	Tragos acetabulum...	Gold. 5. f. 9.	...	...	*	...	...	Keldenich in the Eifel.	
2.	— capitatum.....	id. ib. f. 6.	...	...	*	...	...	Bensberg.	
1.	Scyphia conoïdea	id. 2. f. 4.	...	...	*	...	...	Nieder-Ehe in the Eifel.	
2.	— clathrata	id. 3. f. 1.	...	...	*	...	...	Eifel.	
3.	— costata	id. 2. f. 10.....	...	...	*	...	...	ib.	
4.	— turbinata	id. ib. f. 13; Lonsd. Geol. Trans. vol. v. 58. f. 9.	...	...	*	...	...	ib., Plymouth.	
1.	Manon cribrosum	id. 1. f. 10; Phil. pal. fos. 9. f. 26.....	...	...	*	...	...	Brushford, Pilton, Eifel, Rebinghausen.	
1.	Alcyonum echinatum	Stein. 20. f. 11.	...	...	*	...	...	Eifel.	
2.	— punctatum	id. p. 348.	...	...	*	...	...	ib.	
3.	— striatum	id. p. 348.	...	...	*	...	...	ib.	
1.	Spongia globosa	id. p. 347.	...	...	*	...	...	ib.	
2.	— expansa	id. p. 348.	...	...	*	...	...	ib.	
3.	— ramosa	id. ib.	...	...	*	...	...	ib.	
1.	Sertularia antiqua ...	id. 20. f. 1.....	...	...	*	...	...	Gerolstein.	
1.	Cellaria elegans	id. p. 332.	...	...	*	...	...	ib.	
1.	Tubulipora arcuata...	id. 20. f. 2.....	...	...	*	...	...	ib.	
	Incertæ Sedes.								
1.	Tentaculites ornatus .	Murch. Sil. Syst. 12. f. 25.	*	*	*	...	...	Prüm, Wenlock, Gerolstein, Daun, S.; Abentheuer (Hundsruck), Braubach, Daun, Niederrossbach, S.; Torquay, West Ogwell, Néhou, D.	
1.	Pleurodictyum problematicum.	Gold. 38. f. 18. 160. f. 19. vol. ii. p. 286; Phil. pal. fos. 9. f. 24.	*	*	*	...	...		
1.	Receptaculites Neptuni.	Def. Dict. des Sc. Nat. t. xlv. p. 5; Ischadites Königii, Murch. Sil. Syst. 26. f. 11.	*	*	*	...	...	Ludlow, S.; Eifel, Belgium, Rocquigny, D.	

RECAPITULATION*.

Classes.	Genera.	Total Number of Species.	Silurian Species in the Rhenish Provinces.	Devonian and Silurian Species.	Devonian Species.	Devonian and Carboniferous Species.	Carboniferous Species in the Rhenish Provinces.	Species in three Systems.
Pisces	17	50	...	...	50	...	...	...
Crustacea (Trilobites)	12	40	8	7	32	2	1	1
Mollusca, Ord. Cephalopoda	7	217	14	10	199	6	11	2
——— Ord. Heteropoda	2	24	4	6	22	3	...	2
——— Ord. Pteropoda	1	4	1	1	4	...	...	...
——— Ord. Gasteropoda	26	134	8	7	116	16	10	...
Conchifera, Ord. Brachiopoda	12	217	40	30	182	28	18	3
——— Ord. Monomyaria	6	83	16	3	60	5	13	...
——— Ord. Dimyaria	23	174	20	9	145	5	15	2
Annelida	3	5	...	...	6	...	...	...
Radiata	19	61	2	1	59	10	4	3
Foraminifera	indet.	indet.	...	...	indet.	...	...	...
Polyparia	43	113	7	36	107	4	3	2
Incertæ Sedes	3	3	3	3	3	...	...	...
Total	174	1125	123	113	985	79	75	15

* The varieties numbered and mentioned in the tabular list are not included in this recapitulation.

APPENDIX.

DESCRIPTION OF SILURIAN FOSSILS FROM THE RHENISH PROVINCES, BY J. DE CARLE SOWERBY, F.L.S.

PLATE XXXVIII.

Fig. 1 and 2. *Pterinea lamellosa* (Goldfuss, 136. t. 120. fig. 1 and 2). Goldfuss has described and figured only one valve of this species; the other valve is flat, and (as usual in shells of this family) the ears in it are not separated by a sinus from the body of the shell. Loc. Kemmenau (fig. 1), Wipperthal (fig. 2).

Fig. 3. *Pterinea costata* (Goldfuss, 137. t. 120. fig. 4). A remarkably convex species; the specimen shown in this figure is larger than the one figured by Goldfuss. Loc. Kemmenau near Ems.

Fig. 4. *Atrypa curvata* (Anom. *Terebratulites curvatus*, Schl. Pet. Nacht. 1. 68. tab. 19. f. 2). This appears to be the same as described by Schlotheim, but it is difficult to determine from such an imperfect cast. Loc. District of the Eifel.

Fig. 5. *Spirifer speciosus* (Anom. *Terebratulites speciosus*, Schlot. Pet. Nacht. 1. 66. tab. 16. fig. 1). *Trigonotreta speciosus*, Kœnig, Icon. Foss. Sectiles, 3. tab. 6. fig. 71., Bronn. Lethæa Geog. tab. 2. fig. 15. *Spirifer macropterus*, var. Goldfuss, MSS.? There is no character that I am aware of to distinguish this from the *S. speciosus* of Schlotheim, but as the internal structure exhibited by the cast is totally different from that of *Sp. micropterus*, I quote Goldfuss with doubt. Loc. Prüm.

Fig. 6. *Spirifer micropterus*, Goldf. (*Hysterolites hystericus*, Schlot. Pet. 1. t. 29. fig. 1). This shell with its imbricated surface on the three acute lobes of the internal cast produced by two septa diverging from the prominent beak, is well figured by Schlotheim, and it is perfectly distinct from *Sp. speciosus*, which wants the internal septa; nevertheless Goldfuss has considered them both to be varieties of his

Sp. macropterus. A third species is found at Schönecken in the Eifel, which differs from *S. micropterus* in having no furrows near the edge of the central lobe in the cast of the interior, and in the straightness of the septa which form that lobe.

We might be easily led to adopt the structure of the parts about the hinge as of sufficient importance for generic characters, but these shells, and many others, show us that such distinctions would be purely artificial, and could only be employed safely when they occur constantly in union with several other characters.

Fig. 7. *Orthis? strigosa.* Semi-elliptical, longer than wide, flat, with numerous strong, alternately large and small striæ; muscular impressions very shallow, approaching those of *Leptæna.* We have only one valve of this sharply striated shell; the hinge, teeth, and septa are very small. Loc. Haiger Sülbach (Dillenburg).

Fig. 8. *Orthis virgulata.* Orbicular, with a pointed beak, convex, striated; striæ numerous, very regular, and continued to the beak; septa within the beak large. Loc. Haiger Sülbach.

Fig. 9. *Orthis Pecten?* (Silurian System, 638, pl. 21. fig. 9). The specimens are very defective, the name is therefore given with doubt (fig. *a*, portion of the hinge of a Spirifer).

Fig. 10. *Orthis obovata.* Obovate, depressed, beak-pointed; margin internally striated; hinge-line short; septa long; muscular impressions united, large. Loc. Haiger Sülbach.

Fig. 11. *Orthis partita.* Semi-elliptical, longer than wide, very convex; beak short, divided by a central septum; internal margin ribbed. This has several characters in common with *Leptæna.* Loc. Haiger Sülbach.

Fig. 12. *Orthis circularis.* Orbicular, flat?, margin striated within; beak very small; hinge-line and septa very short; muscular impressions flattened. The larger (convex?) valve unknown. Loc. Daun, in the Eifel district.

Fig. 13. *Leptæna* (*Producta?*) *profunda.* Subcylindrical, regularly striated or ribbed to the apex; front very long; edge oblique, elliptical. A very curiously formed shell. If I comprehend it rightly, it is a Leptæna of the same division as those species which are typical of the genus *Producta*, and which are distinguished by the great length of the descending front; it however differs in the form of the prominent beak-like projection seen in the cavity of the cast, in the regularity of the striæ and the total absence of spines. When the structure of the shells of this family is better known, *Producta* and *Leptæna* may prove two good genera, and the fossil before us may become the type of a new genus. Loc. Olpe.

Fig. 14. *Leptæna semiradiata.* Semicircular, twice as wide as long, convex, marked with twenty-five or thirty even radii, which extend about half over the shell and are then lost; the rest of the surface is smooth, or only marked with lines of growth; under valve concave externally. This resembles *L. sericea*, and *L. Lepis* in form; it has short spines on the hinge-line like *L. lata*, but from all these is distinguished by the elegantly radiated surface. Specimens occur in the Eifel twice the length of the figures. Loc. Prüm, Daun, Eifel.

(*a.*) Cast of the outside of the convex valve.

(*b, b, b.*) Cast of the inside of the same valve.

(*c.*) Cast of the outside of the concave valve.

(*d.*) Cast of the inside of the same valve.

(*e.*) Outside of the same valve, with the calcareous substance of the shell remaining.

Fig. 15. *Leptæna explanata.* Half-obovate, nearly as long as wide, flat, irregularly and finely striated. This is a cast of the lower or concave valve, and has the minutely pitted surface and usual characters of *Leptæna* well-marked.

On the same mass are imperfect casts of *Terebratula Stricklandi?*

Fig. 16. *Leptæna plicata.* Semicircular, slightly convex, plaited; plaits about 25, branched near the margin; hinge-line about three-fourths the length of the shell; lower valve nearly flat, with a narrow descending plaited border. A species of *Leptæna,* which bears much resemblance to an *Orthis,* especially *Orthis Flabellulum,* but does not agree with that genus in the form of the hinge. If *Leptæna* and *Producta* were to be considered two genera, this would be a species of *Leptæna.* Loc. Haustig near Siegen.

(*a, a.*) Inside of the upper valve.

(*b.*) Outside of the lower valve.

(*c.*) Inside of the lower valve, all casts.

Fig. 17. *Homalonotus Knightii* (Silurian System, 651, pl. 7. fig. 7). Loc. Daun.

NOTE BY MM. DE VERNEUIL AND D'ARCHIAC, September 10, 1842.

Since our Table was sent to press, we have received the Fifth Number of Count Münster's Beiträge zur Petrefactenkunde. The new species described in it from the Clymenia limestone of Upper Franconia are limited to the following number:—

	Species.		Species.
Calymene	2	Capulus	2
Asaphus	1	Melania	1
Otarion	2	Euomphalus	1
Harpes	1	Turritella	1
Posidonomya	2	Clymenia	8
Avicula	4	Orthoceratites	1
Cardium?	4	Goniatites	1
Lunulacardium	1		
		Total	32

XXVI.—*Description of the Remains of a Bird, Tortoise, and Lizard from the Chalk of Kent.*

By RICHARD OWEN, Esq., F.G.S.

[Read April 29, 1840.]

PLATE XXXIX.

Description of the Remains of a Bird from the Chalk, Pl. XXXIX. fig. 1 and 2.

THE three portions of fossil bone to be first noticed in this paper were obtained by the Earl of Enniskillen from the chalk near Maidstone, and were recognised by his Lordship and Dr. Buckland to belong to a species of bird. The largest portion is the shaft of a long bone, fig. 1, and is nine inches in length, with one extremity mutilated, but nearly entire, and the other broken off. The extremity is expanded; the rest of the shaft of the bone preserves a pretty regular and uniform size, and is slightly bent. It is unequally three-sided, with the sides flat and the angles rounded off, fig. 1 *a*, and measures two inches and a half in circumference.

It differs from the femur of any known bird in the proportion of its length as compared with its breadth, and from the tibia or metatarsal bone in its trihedral figure and the flatness of the sides, none of which are longitudinally grooved. It resembles most the humerus of the Albatross, both in its form, proportions, and size, but differs therefrom in the more marked angles which bound the three sides. The expanded extremity likewise resembles the distal end of the humerus of the Albatross, but is too much mutilated to allow of the exact amount of similarity to be determined.

On the supposition that this fragment of bone is the shaft of the humerus, its length and comparative straightness would prove it to have belonged to one of the longipennate natatorial birds, equalling in size the Albatross.

The form of the bone might warrant the supposition that it was the distal portion of a radius; but this idea can only be entertained by supposing the fossil bird to have been of gigantic dimensions, almost realizing the fabulous 'Roc' of Arabian romance; and the other two portions of bone associated with it, and most probably parts of the same bird, render this last supposition still less probable.

These portions, fig. 2, both belong to the distal end of the tibia, the peculiarly well-marked trochlear extremity of which is sufficiently preserved, although crushed. Their relative size to the preceding bone, on the supposition that it is the hu-

merus, is nearly the same as in the skeleton of the Albatross; and there is no bird now known, north of the equator, with which the fossils can be compared.

All the three fossils exhibit the thin compact external walls and large air-cavities which characterise the texture of the corresponding bones in birds of flight.

Description of the Remains of a Chelonian Reptile from the Chalk, Pl. XXXIX. fig. 5.

The remains of the Chelonian reptile were discovered in the lower chalk at Burham, in Kent. They consist of a few of the marginal plates of the carapace and some smaller fragments of the expanded ribs which form the dorsal bony shield. The marginal plates are four in number, united together by the usual finely indented sutures, and each impressed along its middle and upper surface with a line corresponding to the margin of the horny plate that originally defended it. The external or free margin of each plate is slightly emarginate in the middle. These marginal plates are narrower in proportion to their length than in the *Chelone Mydas* and *Chelone imbricata*, and they deviate still more, in the character of their internal articular margin, from the corresponding plates of the terrestrial *Chelonia*; but they sufficiently agree with the marginal plates of the carapace of the *Emydes* to render it probable that the present chalk fossil is referable to that family of *Chelonia* which lives in fresh waters or estuaries*.

Description of the Vertebral Column of a small Lacertine Saurian from the Chalk. Pl. XXXIX. fig. 3 and 4.

The third fossil from the chalk which I have to notice, is one which Sir Philip Egerton has recently added to his collection; it consists of a chain of small vertebræ in their natural relative position (fig. 4.). The bodies of these vertebræ are united by ball- and socket-joints, the socket being on the anterior, and the ball on the posterior part of the vertebra; and they are proved to belong to the Saurian class of reptiles by the presence of many long and slender ribs, and by the conversion of two vertebræ through the length and strength of their transverse processes into a sacrum. Remains of an ischium and pubis are connected with the left side of this sacrum, proving incontestably that this reptile had hinder extremities as well developed as in the generality of Saurians; but of these, as well as of the anterior extremities and head, there is no trace.

* Subsequent observation of the modifications in the form of the marginal plates and of other parts of the skeleton of extinct *Chelones*, by which the interval separating the existing marine and freshwater species is diminished, has weakened the impression which the character of the marginal plates of the chalk Chelonite first made in favour of its Emydian affinities; and the examination of the nearly entire skeleton of the same species recently obtained from the same quarries at Burham by Mr. Bensted, and described since the reading of the present paper by Dr. Mantell in the Philosophical Transactions, has demonstrated that it is not an *Emys*, but a true *Chelone*, or marine Turtle.—April 1842.

With this evidence of the primary group of reptiles to which the fossil belongs, there next remained to be determined to which division of Saurians having ball and socket vertebral joints it was to be referred. In the Crocodilian, or Loricate group, the transverse costigerous processes are elongated, the posterior ribs are exclusively attached to these processes, and three, four or five of the vertebræ which precede the sacrum are ribless, and consequently reckoned as lumbar vertebræ; in the Lacertine Saurians there are never more than two lumbar vertebræ, and all the ribs are supported on short convex processes or tubercles.

In the present fossil each rib is articulated by a single head to a short process of this kind, and they are attached to all the vertebræ except the one immediately preceding the sacrum: these characters, with the slenderness and uniform length of the ribs, and the degree of convexity in the articular ball of the vertebræ, prove incontestably that the fossil is part of a Saurian appertaining to the inferior or Lacertine group.

The costal tubercles are developed, as in other Lacertians, from the sides of the anterior part of the body of the vertebræ; the under surface of the vertebra is smooth, concave in the axis of the body, and convex transversely.

As there are twenty-one costal vertebræ anterior to the sacrum, including the single lumbar, the fossil cannot be referred to the genera *Stellio*, *Agama*, *Leiolepis*, *Lyriocephalus*, *Basiliscus*, *Anolis*, or *Chamæleon*; but a comparison may be instituted between it and the Monitors, Iguanas, and Scinks. In the absence of cranium, teeth and extremities, any closer approximation of the fossil to existing forms would be hazardous, and too conjectural to yield any good scientific result; and the subjoined figure supplies the place of further verbal description of the proportions of the different vertebræ.

If the portions of the lower jaw of a Lacertian from the lower chalk, near Cambridge, should be of the same species, as it agrees in size with that above described from the same formation in Kent, there would then be no doubt that the chalk Lacertian is generically distinct from any known existing Lizard. Fig. 3. Pl. XXXIX. is a side-view of a portion of the lower jaw of the Lacertian reptile from the lower chalk near Cambridge. It contains twenty-two close-set awl-shaped teeth, anchylosed by their bases to an outer alveolar parapet of bone, as shown at fig. 3*b*. I have proposed the name of *Raphiosaurus* for the genus indicated by this fossil.

XXVII.—*On the Distribution of the Erratic Boulders and on the Contemporaneous Unstratified Deposits of South America.*

By CHARLES DARWIN, Esq., M.A., F.R.S. and F.G.S.

[Read April 14th, 1841.]

PLATE XL.

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1. *Boulder Formation in the Valley of the Santa Cruz.*

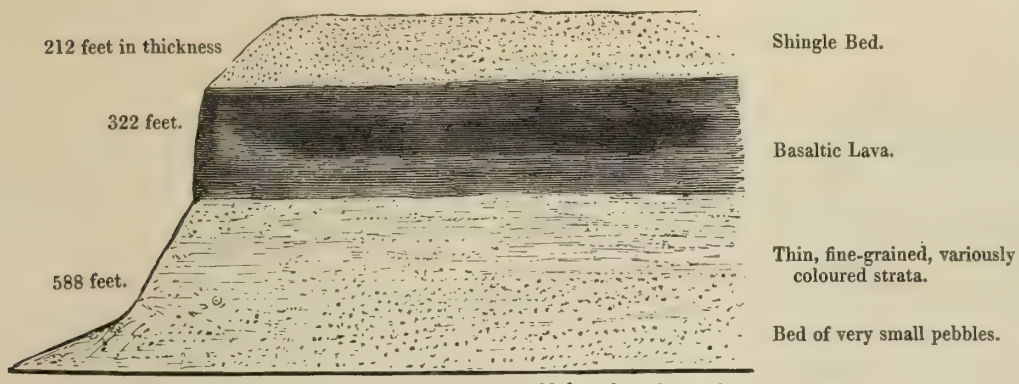
DURING the survey of the shores of South America, southward of the Rio Plato, by Capt. FitzRoy in H.M.S. Beagle, I did not meet with any boulders on the eastern plains of the continent until we arrived on the banks of the river Santa Cruz, in lat. 50° 10′ S. Nor did they occur there near the coast, but were first noticed in ascending the river at the distance of about 100 geographical miles from the Atlantic, and 67 from the nearest slope of the Cordillera. Twelve miles further west, in lon. 70° 50′ W., that is, fifty-five miles from the mountains, they were extraordinarily numerous; consisting of compact clay-slate, feldspathic rock, a quartzose chloritic schist, and basaltic lava; and they were generally of an angular form, and many of them resembled fragments of rock at the foot of a precipice. The size of some was immense: I measured a square one of chloritic schist, which was five yards on each side and projected five feet above the ground; a second, which was more rounded, was sixty feet in circumference, and stood six feet above the ground; how much of each was buried beneath the surface I could not ascertain. There were innumerable other fragments from two to four feet square. The vast open plain on which they lay scattered, is 1400 feet above the level of the

sea; its surface is somewhat but not greatly irregular, and the inequalities appear to have been caused chiefly by the denudation of loose matter from an irregular field and hummocks of lava. The plain slopes very gently and with much regularity to the Atlantic, where the sea-cliffs are about 800 feet high; it rises somewhat more abruptly towards the Cordillera, near which its height is above 3000 feet. The Cordillera in this latitude are not very lofty, the highest pinnacle being only 6400 feet above the level of the sea.

The accompanying section (Fig. 1.), exhibited on the banks of the river in the

Fig. 1.

Surface of plain, strewed with great angular erratic boulders, 1400 feet above the level of the sea.



River Santa Cruz: here 280 feet above level of sea.

longitude above referred to, will give a sufficient idea of the composition of the plain on which the boulders lie. The upper bed is 212 feet in thickness, and exhibits indications of being coarsely stratified. It is composed of well-rounded shingle with great angular blocks strewed on the surface, and probably imbedded (for owing to the state of the section I was unable to ascertain this point) in the whole upper part of the stratum. The shingle bed is continued without interruption to the coast, and is there certainly of submarine origin. From its general similarity throughout this space, I have no reason to doubt that the whole was accumulated under similar circumstances. The lowest bed represented in the section is composed of minute pebbles of the same varieties of rock, with the exception of those of basaltic origin, as the great boulders on the surface. The contrast in the means of transportal from the same source, afforded by the regularly sifted minute pebbles of the lowest bed and the huge angular fragments of the uppermost, separated by a great stream of lava and a deposit of fine sediment nearly 500 feet thick, appears to be worthy of notice.

The valley in which the Santa Cruz flows, widens as it approaches the Cordillera, into a plain, in form like an estuary, with its mouth (see map, Pl. XL.) directed towards the mountains. This plain is only 440 feet above the level of the sea, and

in all probability it was submerged within, or nearly within, the post-pliocene period. I am induced to form this inference from the presence of existing sea shells in the valley, and from the extension far up it of step-like terraces which on the sea-coast, certainly are of recent submarine origin. Round the estuary-like plain, and between it and the great high plain, there is a second plain, about 800 feet above the sea-level, and its surface consists of a bed of shingle with great boulders. In this part of the valley, namely, between thirty or forty miles from the Cordillera, there were, in the bed of the river, boulders* of granite, syenite and conglomerate, varieties of rock which I did not observe on the high plain; and I particularly noticed that there were none of the basaltic lava. From this latter fact and from several other circumstances, more especially from the immense quantity of solid matter which must have been removed in the excavation of the deep and broad valley, we may feel sure that the boulders on the intermediate plain and in the bed of the river, are not the wreck of those originally deposited on the high plain. These boulders, therefore, must have been transported subsequently from the Cordillera, and after an interval during which the land was modelled into the form above described. Those on the lowest plain must have been transported within, or not long before, the period of existing shells.

I have said that the first erratic block which I met with, was sixty-seven miles from the nearest slope of the Cordillera; I must, however, record the case of one solitary rounded fragment of feldspathic rock lying in the bed of the river, at the distance of 110 miles from the mountains. This fragment was seven feet in circumference, and projected eighteen inches above the surface, with apparently a large part buried beneath it. As its dimensions are not very great, we may speculate on some method of transportal different from that, by which the plain near the mountains was strewed with such innumerable boulders; for instance, of its having been imbedded in a cake of river ice. Its solitary position is, however, a singular fact.

I met with erratic boulders nowhere else in Patagonia: Captain King, however, states, in his "Sailing Directions," that the surface of Cape Gregory, a headland of about 800 feet in height, on the northern shore of the Strait of Magellan, is strewed with great fragments of primitive rocks.

2. *Tierra del Fuego and the Strait of Magellan.*

The eastern part of Tierra del Fuego is formed of large outliers of the Patago-

* I may observe, that it can be clearly shown (Journal of Researches, p. 216) that the river itself, although large and rapid, has scarcely any power in transporting fragments even of inconsiderable size.

nian formation, fringed by deposits of much more recent origin, the height of which varies from about 100 to 250 feet. These lower, irregular plains have been elevated within the post-pliocene period. They consist of fine-grained, earthy or argillaceous sandstone, in very thin, horizontal, but sometimes inclined laminæ, and often associated with curved layers of gravel. On the borders, however, of the eastern parts of the Strait of Magellan, this fine-grained formation often passes into, and alternates with, great unstratified beds, either of an earthy consistence and whitish colour, or of a dark colour and of a consistence like hardened coarse-grained mud, with the particles not separated according to their size. These beds contain angular and rounded fragments of various kinds of rock, together with great boulders. At Elizabeth Island, within the Strait, there are good sections of this deposit in cliffs 150 feet high, and composed chiefly of whitish earth, with fragments of syenite, greenstone, feldspathic rocks, clay and hornblendic slates and quartz, most of which do not occur, *in situ*, in the neighbourhood. These fragments are generally arranged without the slightest trace of order,—large and small, angular and rounded being close together; but in some parts of the cliff, the mass is divided by beds of stratified shingle, and these are most frequent in the upper part,—a fact which I observed in other places.

Few of the fragments much exceed in size a man's head, but there are numerous large boulders on the beach. In the cliff at Cape Negro, which is close to Elizabeth Island, and is of the same height and of nearly the same nature, I saw a great boulder imbedded. This deposit at Nuestra Señora de Gracia is rather finer grained, and contains fewer fragments; some of which are perfectly rounded, some quite angular; and a single one, of considerable size, is often imbedded by itself in fine-grained and fine-laminated matter. I here, also, observed a boulder at least four feet in diameter, projecting from the face of the cliff. In a neighbouring cliff, a whitish mass fills up hollows in an underlying finer-grained bed. North of Cape Virgins, close outside the mouth of the Strait, the cliffs are between 200 and 300 feet in height; and they consist of an argillaceous sandstone in horizontal laminæ, as fine as roofing-slate, which in several places is interstratified with two or three beds of the coarse nature just described, each stratum being from five feet to twenty thick. These beds often thin out and become curvilinear at each end. The imbedded fragments are of the same nature and shape as before mentioned; and their parent rock cannot be less, and probably is considerably more, than 120 geographical miles distant. In the other cases above described, the distance must be at least sixty miles. The mountains, from which they all probably came, lie west and south-west.

The numerous boulders before noticed on the beach at the foot of the cliffs on Elizabeth Island, consist of the same varieties as the smaller imbedded fragments,

and are from one to four feet in diameter; the outline being irregularly angular, with only the edges blunted. In the other places above mentioned, and likewise at the base of the mountains on the line of coast extending south to Port Famine, boulders are numerous on the sea-beaches. Although I saw only two in the cliffs, yet as the boulders do not, as far as I was able to observe, occur scattered on the surface of the ground, and as a large area has evidently been denuded, I concluded that most of the blocks were originally enclosed in the deposit, and that after they were washed out, they had been driven onwards by the surf during gales, and collected at the foot of the retreating cliffs. At St. Sebastian's Bay, however, on the east coast of Tierra del Fuego, this explanation is scarcely applicable, for many gigantic boulders there lie in a protected position at the base of a naked cliff about 200 feet in height, and entirely composed of thin strata of fine-grained sandstone, with a few layers of small, well-rounded pebbles. As it is very improbable that the boulders were ever included in a deposit of this nature, we must suppose that they were originally thrown down either on the surface or in a thin superficial bed, which has subsequently been removed. I may specify, that one of these boulders, composed of syenite and shaped somewhat like a barn, was forty-seven feet in circumference, and projected about five feet above the sand-beach. There were many others half this size, and they all must have travelled at least ninety miles from their parent rock.

The position of the boulders in St. Sebastian's Bay is, in another respect, interesting; for the form of the land clearly shows, that long anterior to the total amount of elevation attested by upraised recent sea shells, a wide channel (indeed, introduced in all the charts before the voyage of the Beagle) connected the middle part of the Strait of Magellan with the open sea. During the same period, a very low neck of land near Cape Negro, now strewed with boulders and bordered by cliffs of the unstratified deposit, must have formed a straight channel between the great land-locked bay called Otway Water, and the eastern arm of the Strait of Magellan. Shoal Harbour, which lies in this line, is scattered over with enormous angular fragments of rock, projecting from five to eight feet above the level of the sea, and giving to it a singular appearance. The unstratified beds of hardened mud and whitish earth, containing a few boulders and numerous smaller angular as well as rounded fragments, occur only in the neighbourhood of the Strait of Magellan, and are probably connected in their origin with the existence of an ancient channel which had nearly the same direction with the present one: so also it is evident, that the distribution of the numerous great boulders now lying on the surface (whether or not all were originally imbedded in the unstratified deposit) is likewise connected with the course of formerly existing sea-channels. The currents off Cape Horn set almost constantly from the west, as is known to the cost of

all those who have to double it; hence they probably set in a similar direction through the above ancient channels, when more open and less crooked than the Strait of Magellan now is. It is in accordance with this circumstance, that, in the districts just described, and in that which we are immediately to treat of, the boulders and smaller fragments have all travelled from mountains situated to the west.

In a space about forty miles broad at the extreme south-eastern part of Tierra del Fuego, including Navarin and several smaller islands, the shores are fringed at about an equal height, by a deposit very closely resembling the unstratified beds in the Strait of Magellan. On the south side of Navarin Island it forms a small plain (the only level land in that part of the country), fronted by a line of cliff several miles in length, and about sixty feet in height. In this cliff there is not a trace of stratification; and the earthy, rather argillaceous mass contains fragments, some angular, but mostly rounded, of all sizes, from mere particles to great boulders, of nearly the same composition as the fragments in the Strait of Magellan. Similar rocks do not occur *in situ* within sixty miles; and probably some exist only at a considerably greater distance. Within the eastern mouth of the Beagle channel, forming part of the above-mentioned area, the cliffs are higher, and the beds are sometimes regularly interstratified with layers of shingle. I cannot more accurately describe the appearance of the cliffs around Navarin Island, than by the remark which, at the time, I entered in my note-book, "that a vast debacle appeared to have been suddenly arrested in its course." But this explanation always appeared to me, from the width and openness of the channels both to the east and west, and from the proofs of the very gradual elevation of the land in the neighbouring countries, to be encumbered with the greatest difficulty. Hence the origin of these beds, as well as of those in the Strait of Magellan, which, although unstratified, are of submarine formation, remained quite inexplicable to me. This deposit resembles the till of Scotland, the boulder formation of Northern Europe and of the eastern coast of England, in the following respects, which clearly indicate, as Mr. Lyell* has remarked, some peculiar origin; first, in the entire absence of stratification in one part of a bed, which in another shows, either throughout its whole thickness or in alternate beds, signs of regular deposition; secondly, in the close juxtaposition of fragments of far-transported rocks, varying in size from minute pebbles to boulders, some being rounded and others angular; and lastly, as I believe, in the frequent occurrence of a capping of gravel. Mr. Lyell, after having examined this kind of deposit (which for briefness I will call by the Scotch term 'till') in the several countries above specified, ascribes its origin to the deposition, in a tranquil sea, of mud, sand and blocks, from melting drift-ice;

* Mr. Lyell on the Boulder Formation of East Norfolk. Philosophical Magazine, 1840, p. 348.

but in the area, near the eastern mouth of the Strait of Magellan, where the finest sediment has been arranged in horizontal laminæ, and the coarse shingle in beds, it appears strange that stratification should be so entirely, and often suddenly, absent in the till alone. The mere dropping of the fragments seems hardly sufficient to explain this; for we have seen that both angular and rounded fragments sometimes occur imbedded in the finest laminated matter. Perhaps the disturbing action of the icebergs when stranded, as suggested by Mr. Lyell, may account for this remarkable deficiency of stratification in the till.

I will only further add, that I looked in vain for any marine remains in these till-deposits, and a similar deficiency has been remarked in those of Europe. We must not suppose that their absence can be accounted for by a bottom of this nature being unfavourable to the existence of marine animals, for both in the retired and only partially protected bays of Tierra del Fuego, kelp (*Fucus giganteus*) grows in a depth of from two to twenty fathoms on the loose round stones, and between the roots of the kelp innumerable creatures live: in the open sea also, where there was no kelp, I found numerous *Terebratulæ* and other shells, on stones lying in mud. But when we reflect how great a number of icebergs, some charged with foreign matter, but very many more without any, must, on the above theory, have been drifted to the spot while the till was accumulating; and that these icebergs being lifted up and down by the tides, as well as being broken into pieces and many times stranded, would plough up large tracts of the bottom of the sea, part of the difficulty in explaining the absence of marine remains in the till is removed, for we can hardly conceive the existence of any animal on a soft bed of mud and stones, disturbed at intervals with great violence.

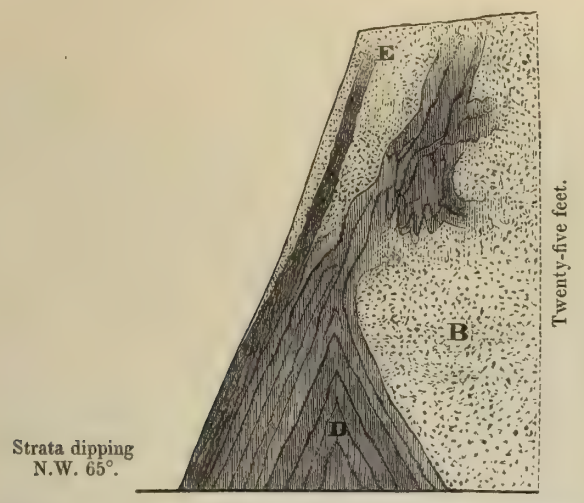
An interesting description is given by Wrangell* of the fragments of ice off the coast of Siberia, often raised into a vertical position, and which, to use his words, "are driven against each other with dreadful crashes, are pressed downwards, and reappearing again on the surface covered with the torn up green mud, which we had often seen on the highest hummocks." The particular case thus described happened 100 miles from the main-land, where the water however was only about fifteen fathoms deep: many of the hummocks were about 100 feet high. Wrangell states, that within the line of large hummocks the sea was generally tranquil, and strewed with only small fragments of ice; so that in this case undisturbed strata of gravel or other matter might easily (during the gradual elevation of the land, believed to be there in progress) accumulate over the disturbed beds; and in these latter deposits it is not probable that any organic remains would be enclosed.

There are two sections at Gregory Bay, in the eastern part of the Strait of

* Wrangell's 'Voyage to Siberia and the Polar Sea,' translated by Major Sabine, p. 257.

Magellan, which are worthy of description. The cliffs are composed of the usual blackish indurated till, in some places interstratified with yellowish argillaceous sandstone, including a few large pebbles. In one cliff about twenty-five feet high (Fig. 2, which is traced from an outline made upon the spot), the main part con-

Fig. 2.



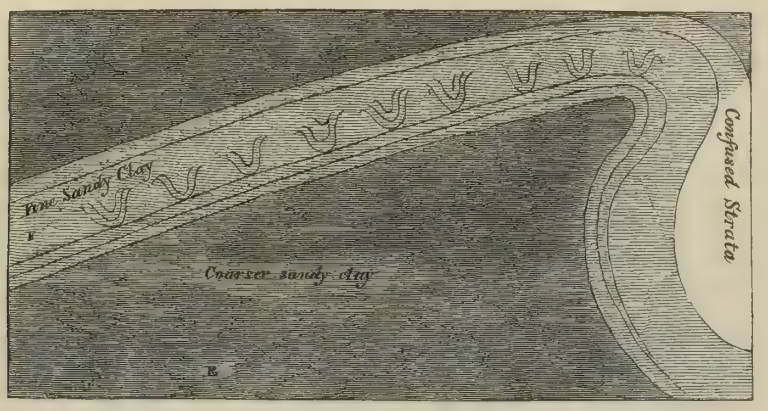
B. Yellow sandy mud.
D. Blackish mud or sandy clay.
E. A stratum which gradually disappeared in the surrounding mass; its included layers were much convoluted.

Gregory Bay in the Eastern Part of the Strait of Magellan.

sists of finely laminated yellow mud (B), which, a little further to the right, includes many fragments of rock and loses its laminated character. On the left it alternates with layers of blackish mud (D), which are inclined at an angle of 65°, and at the foot of the cliff form a regular saddle. Many of these layers lose themselves in the yellow sandy mud in the most singular convolutions. In another cliff, Fig. 3. a bed, about eighteen inches thick and thirty feet in length, of fine sandy clay, lying in a coarser sort, dips gently at one end, and at the other is bent back under itself. The subordinate layers in this stratum are curved in basin-, or rather urn-shaped folds about a foot wide, and are placed at nearly equal intervals, so as to resemble some architectural ornament. They cannot always be traced from one basin to the other. The extreme degree of their curvature shows that they were not deposited in so many furrows at the bottom of the sea: it may, perhaps, be conjectured, that during the great and unequal pressure to which the whole mass has been subjected, the finer-grained laminated matter of which these urn-shaped basins consist, yielded more readily, and slided in between the parts exposed to a less force. With respect to the agency by which both sections have been contorted, from the general undisturbed state of the whole country and of the imme-

diately joining beds, and likewise from the peculiarity of the flexures in Fig. 2, I could not at the time persuade myself it was by ordinary violence from below, and no other solution occurred to me. Mr. Lyell* has shown, that in the districts

Fig. 3.



Gregory Bay. (For commencement of description see last page.)

in Europe where the till and boulders occur, most curiously contorted layers are directly superimposed on undisturbed beds, and he suggests as one explanation, the lateral force exerted by stranded icebergs. As we have here also the till and boulders, the forcing up and mingling together of these sedimentary deposits, have, perhaps, been effected by this same agency †; an agency, however, which in most cases appears merely to have prevented the separation of the drifted materials into distinct layers.

3. *Island of Chiloe.*

Passing from the extreme southern part of the continent along the west coast, I did not land south of lat. 47°. It was, however, between lat. 49° and 50° that the fragment of granite, described in my Journal, was seen floating on an iceberg twenty miles from its parent glacier, and therefore we may feel sure that erratic boulders occur in this space. Between lat. 47° and the southern extremity of

* Philosophical Magazine, 1840, p. 379: Mr. Lyell on the Boulder Formation, &c., Proceedings, vol. iii. p. 178.

† Capt. W. Graah, in his Expedition to the East Coast of Greenland, states that there is a part of the coast which derives its name of *Puisortok* from ice "shooting up from the bottom of the sea in such a manner and in such masses, as in many years to make it utterly impassable." The cause of this singular phænomenon is unknown. Capt. Graah suggests amongst other causes, that these masses may be the remains of icebergs frozen to the bottom; but is it not much more probable that the icebergs were first driven deeply into the soft bed of the sea, and that they did not become disengaged until their whole upper parts had been washed away and their buried sides loosened by the melting of the ice?

Chiloe I landed on several parts of the seaward coast, but did not notice a single boulder: as, however, it is separated from the Cordillera by intervening high land, the absence of erratic blocks might have been expected.

At Chiloe I again found transported boulders in vast numbers. This island is a hundred miles long, extending from lat. 41° 46′ to 43° 26′; and it lies parallel to the Cordillera, at the distance of about thirty miles from their base. It consists of mica-slate with two volcanic formations, largely bordered, chiefly on the eastern and northern sides, with horizontally stratified beds of tertiary sandstone and volcanic grit; the sandstone in some places passing into a loosely aggregated conglomerate. On the eastern coast the land is indistinctly modelled into successively rising plains, of which the superficial parts, and the whole thickness of some of the lower plains are composed of stratified shingle. This accumulation, where it caps the tertiary deposits, is evidently of subsequent formation; but I do not pretend to distinguish, in all cases, the shingle beds of more recent origin, from the above-mentioned tertiary conglomerate. The boulders occur in extraordinary numbers on the whole line of the eastern and northern beaches, and likewise to the height of at least 200 feet on the land. I saw a few imbedded in the cliffs of gravel; and as many extensive reefs show that there has been much denudation, I presume that many of the masses were originally included in the gravel. The boulders are likewise very numerous on the islets, which lie close to the eastern coast of Chiloe, and are separated from it by channels, which, although very narrow, vary in depth from 50 to more than 300 feet. In two places where I visited the outer or western coast of Chiloe, I did not see any transported blocks, nor did I during a ride of about thirty miles across the central high land.

The boulders consist of several varieties of granite and syenite; those of the latter rock are common on the northern beaches; but all the masses which I noticed thirty miles southward were of granite. Their parent rock probably exists in the Cordillera: an intelligent resident pointed out to me several varieties of syenite and granite at the northern end of the island, which, he assured me, he had seen forming whole mountains in the vicinity of Reloncavi Sound, which is situated in the same latitude: if so, these boulders must have travelled more than forty miles. I saw no granite or syenite in Chiloe, there is certainly none on the northern or on the eastern coast, the whole of which I examined, and I feel pretty sure none occurs in the northern part of the island; but it is not improbable that some of the western heights, which were estimated at 3000 feet, may be formed of granite. If any of the boulders have come from the heights of Chiloe, they have crossed a broad and level border of the tertiary deposits; but it is far more probable that all came from the Cordillera. The larger boulders were quite angular, and resembled fragments at the foot of a steep mountain. One mass of granite at Chacao

was a rectangular oblong, measuring fifteen feet by eleven, and nine feet high: another on the north shore of Lemuy islet was pentagonal, quite angular, and eleven feet on each side; it projected about twelve feet above the sand, with one point sixteen feet high: this fragment of rock almost equals the larger blocks on the Jura. There were very many others from two-thirds to a quarter of these dimensions. The boulders amongst the islets were in fewer numbers and more rounded than those on the open parts of the eastern coast; but I believe this remark applies only to the smaller masses, which may have been rounded subsequently to their first transportal.

The position of the boulders at the extreme northern point of Chiloe, where a headland about 250 feet high is joined to Lacuy peninsula by a quite low neck, deserves further notice. This headland, from the similarity of its composition, height and stratification, must once have been continuous with the coast of Chiloe. The ancient currents of the sea, which almost insulated the headland, deposited on its inland side, and on the opposite coast, beds of regularly stratified shingle. Some boulders were enclosed in these strata, and many very large angular ones of syenite were lying both on the low sandy isthmus, and on its sides at a height of 150 feet; and transported blocks were certainly far more numerous here than in any other part of the surrounding country. Anterior to the elevation, which has taken place within the post-pliocene period, the headland must have been an island, and the present low neck of land the bottom of a channel, open to the rush of tidal waters which flowed between Chiloe and the mainland of America. We thus see, even more clearly than in Tierra del Fuego, that there is an evident relationship between the distribution of the boulders, and the lines of either anciently or now existing straits. From this consideration, I was at first surprised at the occurrence of numerous blocks in the tortuous channels, between the islets and eastern coast of Chiloe; but I overlooked the fact, that, anterior to the modern period of elevation just alluded to, the middle part of Chiloe, in the line of the Lake Cucao, must, from its lowness, have been breached by a transverse channel. Had the space between Chiloe and the Cordillera been converted into land, the boulders, in their position with respect to their probable parent rocks, in their size and angular shape, would have resembled those on the Jura; the blocks of granite now lying between the islets, being the representatives of those which, M. Agassiz has lately shown, occur in the interior valleys of that range.

Of the few imbedded boulders which I saw, most were in the stratified gravel; but I find in my note-book two sections obtained in the southern half of the island, and described as consisting of hardened mud, including angular as well as rounded fragments of far-transported rocks, and in one instance a boulder. These deposits

evidently are similar to those called 'till,' and I feel nearly sure that they were unstratified; but not being then aware of their interest, I merely compared them to the deposits in eastern Tierra del Fuego, and I here record only what I at the time wrote down. On the inner side of one of the Chonos Islands, a little south of Chiloe, in lat. 43° 50′, there are cliffs about 300 feet high, which I likewise only partially described, as formed of blackish hardened mud with scattered pebbles of various sizes, some well rounded, some but slightly: as I especially noted that the gravel in the upper part of the cliff was stratified, I presume there was little arrangement in the lower. In one layer of loose sand at the base of this cliff, where the hardened mud passed into laminated sandy clay, I found a quantity of comminuted marine shells with a fresh aspect, but too much broken to be characterized. At Chiloe also, in one place where a mass of till passed into fine-grained, laminated beds, I found two or three fragments of a *Cytheræa*. I must, however, observe, that the absence of marine remains in these beds of till, is much less remarkable than in those of Great Britain, because the surrounding stratified formations here contain but very few shells. Indeed in Chiloe I found none, excepting where the sandstone contained calcareous concretions.

With respect to the age of the boulder formation of Chiloe, and I may add, of Tierra del Fuego, I have no precise information. The whole east coast of the island has been elevated certainly from twenty to forty feet, and probably much more, within the post-pliocene period; for on the peninsula of Lacuy (near where I have described the boulders on the low neck) I found, at a height of 350 feet, a great bed of existing shells, out of which forest trees were growing. I have stated, that in eastern Tierra del Fuego the boulder formation has also been elevated within this same period. Without we suppose that the boulders were deposited in a deep sea, which does not appear very probable from the nature and stratification of the accompanying deposits, or without we suppose great oscillations of level of the land, the boulder formation must have been accumulated since the commencement of the post-pliocene æra, or but little before it. From indirect evidence, also, and therefore to be received with limited confidence, I came to the same conclusion with regard to the boulders on the lower plain at Santa Cruz. It is worthy of notice, that geologists have referred the dispersal of the boulders which lie scattered over the temperate parts of the northern hemisphere to this period.

I have stated in my Journal, that northward of Chiloe (lat. 41° 47′) I met with no fragments of far-transported rock which can be classed with the erratic boulders just described;—their great size, frequent angularity, and complete separation by wide valleys or arms of the sea from their parent source, being taken as their distinctive characters: I had opportunities of observing them in the country around Valdivia, Concepcion, and many parts of central and northern Chile. In these

same districts I did not meet with any beds of till. North of the Strait of Magellan, on the sea-shores of Patagonia* and La Plata, neither boulders nor beds of till occur in the same latitudes, under which both are present on the Pacific. With respect to the erratic masses, we may infer from what has been shown in the ascent of the Santa Cruz, that their absence is owing to the wide space separating the shore of the Atlantic from the Cordillera. In my Journal I have endeavoured to show in detail, that, in the northern parts both of the Old and New World, and in the southern parts of South America, the dispersal of boulders has been limited, in approaching the tropics, to nearly the same latitudes, and that no true blocks of this description have been observed in the inter-tropical regions†; and we may now be permitted to suspect that beds of 'till' will be found to be confined to the same parallels of latitude as the boulders.

4. *Remarks on the Glaciers of Tierra del Fuego, and on the Transportal of Boulders.*

In the remainder of this paper I will make a few remarks on the glaciers of Tierra del Fuego, and on the means of transportal of the boulders. I had no opportunity of landing on any glacier, but we passed in the Beagle and Magdalen channels within two miles of several. The mountains were covered with snow, and the glaciers formed many short arms, which descended to the beach, and terminated in

* I may here mention, that on East Falkland Island, although situated in the same latitude with Tierra del Fuego, and lying only 250 miles eastward of it, and with mountains above 2000 feet in height, I did not observe any erratic boulders. As it may occur to some geologists that the island may have received its chief elevation, subsequently to the period of the dispersal of the boulders on the main-land, I will observe, that the facts are directly opposed to such a view, for I could not find any elevated marine shells on this island; whereas I did not land on a single point of the coast of Patagonia, or of eastern Tierra del Fuego, without meeting with them.

† In my Journal (p. 289, and Appendix, p. 615), where I have considered the *apparent* exceptions to this statement, I accidentally omitted one case. Near Rio de Janeiro I met some large-sized boulders of greenstone, containing iron pyrites; they were perfectly rounded, and therefore wanted that character of angularity, which, though far from being always a concomitant, may, where it is present, be considered as eminently distinctive. I could not see the greenstone *in situ* in the immediate neighbourhood, but the extreme rankness of the vegetation quite precluded accurate investigation. Mr. Caldcleugh (Travels, vol. ii. p. 195) observed greenstone boulders on the road to Villa Rica, and Spix (Travels, Eng. Transl. vol. i. p. 272) observed others on the road to Santa Cruz. Mr. Fox, Minister Plenipotentiary at Rio de Janeiro, informed me that he found similar blocks on the islands of St. Sebastian and St. Catherine, and at Port Alegre on the southern coast of Brazil. Nevertheless, it is not improbable that in all these cases the parent rock was not far distant. I found two greenstone dykes near Rio de Janeiro: Von Eschwege mentions others, and Mr. Fox observed one on St. Sebastian. Besides many obvious means of transportal to moderate distances of large fragments of rock, now that geologists generally admit that most countries have undergone slow oscillations of level, we must not overlook the power which the surf during gales would have, on an exposed and gently inclined surface, of driving onwards blocks of rock from the top of one line of beach to that of another, as the sea gradually encroached on the land.

low perpendicular cliffs of ice. The surface of these glaciers, even to a considerable height on the mountains, was of a bright azure colour and perfectly clean, as were the floating fragments. This is what might have been expected, from the shortness of the glaciers, from their not being bordered by precipices, and from their not being formed by the junction of two or more smaller streams of ice. Although the chief characteristic of the climate of the southern parts of South America seems to be its equability, yet the glaciers cannot descend very slowly, for large masses are continually breaking from the cliffs of ice. We were witnesses of one fall in the Beagle channel; and the water was strewed with smaller pieces: Capt. King* mentions several bays and channels in Tierra del Fuego almost choked up with them; Mr. Bynoe† informed me that as many as fifty icebergs were seen together in Sir G. Eyre's Sound: behind the peninsula of Tres Montes, in a latitude corresponding to that of the lake of Geneva, some Spanish missionaries‡, in an account of their voyage, describe an arm of the sea as crowded with icebergs of all sizes. Some of the fragments of ice which are thus detached are of immense size: Mr. Kirke§ met with one in an inland creek, situated in the corresponding latitude as Paris, which was estimated at forty-two feet in height, and was aground, where bottom could not be obtained with a line of 126 feet. This mass was therefore at least 168 feet in height, equal to a lofty church: how violently must the tranquil waters of the retired creek have been agitated when it fell! Capt. King, describing another case‖, compares the crash to a broadside reverberating through these lonely regions. In the Beagle channel the insignificant fall which we witnessed, caused a wave that nearly destroyed our boats, though hauled up on the shore, and at the distance of half a mile from the cliff of ice. These waves seem to displace and drive before them the fragments of rock lying on the beach. Although the glaciers I saw were quite clean, many of the icebergs described by Mr. Kirke in Sir G. Eyre's Sound were dark coloured, and on the surface of one, several blocks of granite and serpentine were found.

The glaciers in the Beagle channel were generally bordered by a tongue of land, formed of huge fragments of rock, and many boulders were strewed on the neighbouring shores. The only glacier which I approached closely, descended to the head of a creek, formed on one side by a wall of mica-slate, and on the other by a broad promontory, about fifty or sixty feet high, and apparently composed entirely of enormous fragments, chiefly of granite. One of these was ninety feet in circumference, and projected six feet above the sand. This promontory, which originally no doubt was a lateral moraine, projects nearly half a mile beyond the

* Voyages of the Adventure and Beagle, vol. i. pp. 56, 58, 140, 258.

† The Author's Journal of Researches, p. 283.

‡ Ibid., Appendix, p. 613.

§ Voyages of the Adventure and Beagle, vol. i. p. 337.

‖ Ibid., vol. i. p. 140.

extremity of the glacier, and is in parts covered by old trees: hence we must infer, that the glacier formerly extended considerably further than it now does.

It would be useless even to allude to the difficulties which affect every theory of the transportal of erratic boulders, excepting that by the agency of ice; but after the remarkable discoveries of Venetz, Charpentier, Agassiz, and others, of the great extension in Europe of moraines formed by ancient glaciers, it is necessary to observe, that neither the 'till' beds of eastern Tierra del Fuego, which pass into and are regularly interstratified with a great formation of horizontally laminated sandstone, containing marine remains; nor the stratified gravel and till, which form low plains on the shores of Chiloe, and cap in regular beds the tertiary strata, can have been produced like ordinary moraines; and, therefore, that the imbedded boulders cannot have been propelled by the glaciers themselves. I am led to the same conclusion with respect to the till of southern Tierra del Fuego, which forms a level plain and a fringe around several islands, and which in one part passes into a regularly stratified deposit. The boulders on the lower levels at the head of the Santa Cruz river are strewed on land, which certainly has been modelled by the action of the sea. Those on the 1400 feet plain are sixty-seven miles from the Cordillera, of which the highest pinnacle is only 6400 feet, and the general range considerably lower; this little inclination of the surface, with the absence of mounds or ridges on it, and the angularity of the fragments, are opposed to the notion that the blocks have been pushed to this great distance by glaciers. Hence I conclude, that in the two first-mentioned districts it is quite certain, and in the three latter highly probable, that the boulders were transported by floating ice.

The fact of many of the blocks on the northern end of Chiloe being different from those thirty miles southward, where there must anciently have been a channel across the island, is not opposed to the foregoing conclusion: for the tidal currents must have drained, according to the number and position of the seaward channels, determinate spaces of the area between Chiloe and the Cordillera; and according to the situation of the spot whence the iceberg with its cargo of rock was first launched, so would it be swept towards one or the other channel. The varying winds, no doubt, would partly influence the course of icebergs, but, from their floating very deeply, the currents would act far more powerfully on them. Nor is the circumstance of the boulders on the high and low plain of Santa Cruz being of different kinds of rock any difficulty; for after the change of level in the land, necessary to account for the existence of the lower plains, we might have anticipated that some of the glaciers which formerly debouched on the coast would cease doing so; and that rocks hitherto submerged beneath the sea would become exposed, and their fragments falling on the glaciers would be transported with the icebergs.

It appears that masses of floating ice, by which fragments of rock are conveyed, are produced in two ways, and under circumstances considerably different although often acting together, namely, by the breaking off of icebergs from glaciers descending into the sea, and by the actual freezing of the surface of the sea or its tributary streams. Great boulders can be included in ice by this latter means only (with rare exceptions) where the winter is extremely cold, as in the Gulf of Bothnia and on the shores of North America. A large proportion of the fragments thus enclosed will generally have been exposed to the wearing influences of the sea-beach; and from the ice being in a sheet, they will be liable to be repeatedly stranded in shallow places, and thus to become still more worn. The other method of transportal, namely, by the descent of glaciers to the sea-level, and the production of icebergs, is far from necessarily requiring an extremely cold winter; for the low descent of glaciers seems to depend (other circumstances being alike) in a much greater degree on the summer not being hot enough to melt the ice and snow, than on the winter being very cold. Hence, as I have endeavoured to show in my Journal (chap. xiii.), glaciers in South America descend to the sea from mountains not very lofty, and in latitudes extraordinarily low compared with those in Europe under which the same phænomenon takes place; and yet, the vegetable and animal productions of this kind of climate have, in some degree, an inter-tropical character.

M. Agassiz has shown that blocks of rock are not imbedded in the ice of the Swiss glaciers, except high up near their sources, and that those numerous masses which lie on the surface, from not being exposed to much abrasion, remain angular: hence only loose angular blocks of rock (as was the case with those on the floating ice in Sir G. Eyre's Sound) can be transported by icebergs, detached from the glaciers of temperate countries. And to effect this, the icebergs must be floated off perpendicularly and in large masses, for otherwise the loose fragments would be at once hurled into the sea. These remarks do not necessarily apply to icebergs formed under a polar climate, for if a glacier in its descent, reached the sea before the fragments of rock which had fallen on the soft snow had come to the surface, icebergs would be produced with imbedded fragments of rock: I have described in the 'Geographical Journal'* the case of one huge fragment thus circumstanced, seen drifting far from land in the Antarctic Ocean†.

As one of the above two methods of conveying erratic boulders, namely, that by icebergs from glaciers, is now in action on the South American shores, we are na-

* Geographical Journal, 1839, p. 528.

† Dr. Merten's observed many fragments of rock imbedded only just above the level of the sea in the lateraal wall of the glaciers at Spitzbergen, but he never saw any in the cliffs of ice facing the sea.—Edinburgh New Phil. Journal, 1841, pp. 173 and 176.

turally led to conclude, that this was the chief agent in the enormous amount of transportal formerly effected over a more extended area. It would indeed require the strongest evidence to make one believe that the surface of the sea, or even of rivers, between lat. 41° and 42°, had ever been frozen thickly enough to enclose the huge masses of rock which we now find stranded on the island of Chiloe. The angularity of their forms at this latter place and at Santa Cruz, accords with their transportal by icebergs; but it is not improbable that the other agency, namely, the freezing of the sea, may formerly have been instrumental in Tierra del Fuego, and especially in the southern parts of that country, where the boulders frequently show signs of attrition, as if they had been worn on a sea-beach. In endeavouring, therefore, to determine, in any country where boulders occur, the nature of the climate during their dispersal, we should attend not only to the character of the contemporaneous organic productions, but likewise to the shape of the fragments and to their position; for these circumstances would aid us in discovering whether they had been imbedded in sheet-ice, or carried on the surface of deeply-floating icebergs.

XXVIII.—*On the Geology of the South-east of Devonshire.*

By ROBERT ALFRED CLOYNE AUSTEN, Esq., F.G.S.

[Read 1834, 1836, 1837, 1839, 1840*.]

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Introduction.

THE range of Dartmoor, independent of geological considerations, forms the most natural division of the county of Devon; and the following pages relate only to the

* In this memoir are given in a condensed form the substance of the following papers:—1. An Account of the raised Beach at Hope's Nose, read Nov. 19th, 1834. See Proceedings, vol. ii. p. 102. 2. On the part of Devonshire between the Exe and Berry Head and the coast and Dartmoor; read May 25, 1836. Proceedings, vol. ii. p. 414. 3. On the Geology of the South-east of Devonshire; read Dec. 13, 1837. Proceedings, vol. ii. p. 584. 4. On the Structure of South Devon; read April 24, 1839. Proceedings, vol. iii. p. 123. 5. On the Bone Caves of Devonshire; read March 25, 1840. Proceedings, vol. iii. p. 286.

southern portion, but which includes perhaps a greater number of distinct formations; presents them under circumstances more favourable for their study; and illustrates more points of geological interest than any other tract of equal extent in England. The object of the memoir is to describe, 1st, The several sedimentary formations; their mutual relations, and organic remains. 2nd, The igneous rocks. 3rd, General conditions; the amount of successive change and local disturbance.

General View of the Deposits of South Devon.

1. *Actual Period.* (Map, Pl. XLI.)

§ 1. *Estuary deposits.*—Along the south coast of England, from the district where the older rocks first show themselves, all the rivers pour their waters into salt or brackish tidal estuaries, some of which are of considerable size; and it is necessary to notice them and certain points connected with such bodies of water, to enable the reader to appreciate the evidence from which we infer that the estuaries were at a former period more considerable, and that other valleys were once estuaries which have now ceased to be so. The rocks which bound the terminal valley of the Teign are, in the lower part, sandstones and conglomerates of the new red series; and, in the upper, inferior rocks; the length of the estuary being about five miles, but its breadth when full is less than one. At low-water this space presents long banks of sand and of mud, black and fetid, from the abundance of decomposing vegetable matter, but between the banks a few streams of fresh water find their way: at high tide the whole area is submerged, and the water reaches the base of a line of low cliffs on each side. Such also are the features of the estuary of the Exe and of others to the westward.

The species of mollusca living in these estuaries are few. The common Mytilus occurs only near the openings with the sea. *Cardium edule*, *Mactra compressa*, *Venus verrucosa* and *V. reflexa*, ascend much higher, and are very numerous; and many curious instances may be observed of the power which some marine animals acquire of adapting themselves to alternate change. When tides are low, and the volume of the Teign considerable, the banks in which these mollusks live are covered by fresh water; yet the animals do not perish. A short distance above West Teignmouth are some sandstone beds, which are tenanted by a colony of the *Pholas dactylus*, and from which remarkably fine specimens may be procured; yet at low-tide the beds are covered by a stream of fresh water, which flows over them from the land. In like manner, the Teredines, which entirely destroyed the piles of Teignmouth Bridge, were constantly exposed to fresh water for several hours. But though the marine conchifera can thus accommodate themselves to change, the Uniones and other fluviatile shells never, that I am aware, descend into the estuary; so that there is always a considerable area which affords no testacea, a circumstance which may account for the paucity of such remains in valleys now abandoned by the sea.

§ 2. *River sand and gravel.*—The production of river sand and gravel, and the forms of fluviatile pebbles as distinguishable from marine shingle, are facts familiar to most observers. It is likewise well known that all streams which take their rise in upland regions have their channels strewed with blocks; yet the power of transport

which the rivers of South Devon occasionally exert will probably appear incredible to the casual visitor; but whoever is interested in such inquiries will be able to collect much information in the upper parts of the courses of the Erme, the Dart, and the Teign.

§ 3. *Marine beds.*—The accumulations in progress over the bed of the sea vary in character with the depth of the water; coarse materials being seldom found beyond the ten-fathom line; from that to forty, the sands decrease in coarseness, and deeper still is only mud or ooze. We know from soundings that in some places the teeth of certain fishes, and that in others certain shells, are peculiar to particular banks,—a grouping of individuals of the same species, of which we find such frequent instances in regular deposits, particularly in the crag. If therefore at the present time very different suites of organic remains are being buried in the contemporaneous accumulations of even inconsiderable areas, we seem hardly warranted in making the use we now do of the fossil forms of the older formations. If also we confine our observations to the natural productions of that small portion of the coast of the south-west of England which belongs to the district here described, it will be found to present peculiarities which must of necessity be perpetuated.

In the south-western parts of England the fern tribe bears a larger proportion to the rest of the vegetation than elsewhere; thus in the valley of the Dart, above Ashburton, the *Osmunda regalis* occurs in greater abundance than in the whole of the rest of England. It is equally common in certain valleys of the south and west of Ireland. This remarkable fern could not be carried down into the present sea by any streams east of the Teign.

The teeth of the hake occur in great numbers on certain banks at the opening of the Channel, but from the known range of this Mediterranean fish, its remains will be limited to our south-west shores: in the same manner, about twenty-five other species common in the Mediterranean seldom range further east than the waters of West Bay. So also the testacea which will in future ages characterize these same deposits will contain as many as seventy species common in the Mediterranean; or in the same manner as the faluns of Touraine differ from the contemporaneous crag of England in the more southern character of its shells, so will the actual deposits off the coasts of Devon and Cornwall differ from those of the Northern and German seas*.

The following list contains such living shells as are peculiar to the coasts of South Devon and Cornwall, together with such as are common there, but comparatively rare on the eastern and northern coasts; the numerical proportion of certain species being, I conceive, in comparisons of this sort, of greater value than the rare occurrence of any particular shell.

The letters M. P. T. B. mark that the species occurs in the Mediterranean, or fossil in the pliocene deposits of Italy or Sicily, in the faluns of Touraine, or near Bordeaux.

Spirula australis, *Lamk. Anim. sans Vert.*
Bulla aperta, *Linn. Syst. Nat.* M.
—— cylindracea, *Pennant, Brit. Zool.* M., B.
Bulla hydatis, *Linn.* M.
—— lignaria, *Linn.* M., T., B.
Ianthina fragilis, *Lamk.*

* See the notice of Mr. Lyell's paper on the Faluns of Touraine, Proceedings Geol. Soc., vol. iii. p. 437.

Turritella exoleta, *Lamk.*
——— truncata, *Linn.*
Natica glaucina, *Lamk.* T., B., It., Sic.
——— nitida, *Fleming.*
Phasianella pallida, *Flem.* (Turbo, *Mont.*)
Turbo albus, *Penn.*
——— cimex, *Linn.* M.
——— costatus, *Turton.* M., It., Sic.
——— lacteus, *Linn.* M.
——— pullus, *Linn.* M.
——— reticulatus, *Montagu.*
——— striatulus, *Linn.* M.
Trochus cinereus, *Da Costa.* M.
——— erythroleucos, *Turton.* M., T., It., Sic.
——— magus, *Linn.* M.
——— papillosus, *Da C.*
Scalaria communis, *Lamk.* M., It., Sic.
——— Turtoni, *Turton.*
Cerithium costatum, *Flem.*
——— reticulatum, *Mont.* (C. lima.) M.
Buccinum lineatum, *Da C.*
——— macula, *Mont.* Med., T., It.
Murex erinaceus, *Linn.* M., T., It., Sic.
——— purpureus, *Mont.* Med., T., B., It.
——— trunculus, *Linn.* M., T., Sic.
——— septangularis, *Mont.*, *F. Duj.* T.
——— turricula, *Mont.*, *F. Duj.* T.
Fusus costatus, *Flem.*
Sigaretus haliotoideus, *Lamk.* B., It., Sic.
——— tentaculatus, *Mont.*
Marginella alba, *Lamk.*
Tornatella tornatilis. (T. fasciata, *Lamk.*)
Velutina otis, *Leach.* M.
——— stylifera, *Turt.*
Haliotis tuberculata, *Linn.*
Calyptræa sinensis, *Lamk.* M., T., B. (C. muricata, *Bast.*)
Pileopsis ungarica, *Lamk.* M., T., B.
Emarginula fissura, *Lamk.* M., T.
Fissurella græca, *Lamk.* M., T. (neglecta.)
Dentalium dentalis, *Linn.* M., It., Sic.
——— entalis, *Linn.* M., T., B., It., Sic.
——— several other species.
Anomia cepa, *Linn.*
——— electrica, *Linn.*
——— fornicata, *Lamk.*
Pecten Jacobæus, *Penn.* M., P.
Pecten lineatus, *Da C.*
——— maximus, *Penn.*
——— obsoletus, *Penn.*
——— tumidus, *Turt. Conchol. Dict.*
Arca barbata, *Linn.* M., T., B., It., Sic.
——— lactea, *Linn.*
——— Noæ, *Linn.* M., T. (biangula, *Bast.*)
Pectunculus glycimeris, *Lamk.* M., T., B. (P. pulvinatus, *Bast.*)
——— pilosus, *Lamk.* M., T.
Modiola barbata, *Lamk.*
——— discrepans, *Lamk.* B.
Lithodomus lithophagus. *Cuv.*
Pinna ingens, *Penn.* M.
——— fragilis, *Penn.* (P. pectinata, *Linn.*)
——— papyracea, *Turt.*
Isocardia cor, *Lamk.* B.
Donax complanata, *Mont.*
——— denticulata, *Linn.*
Tellina crassa, *Penn.* T.
——— donacina, *Linn.* M., T., Sic.
——— fragilis, *Linn.* M., T., It., Sic.
——— lineata, *Turt.*
——— rubra, *Da C.*
——— tenuis, *Da C.* B.
Lucina arcuata, *Mont.*
——— divaricata, *Lamk.* Eo., Mio., & Plio.
——— lactea, *Lamk.* M., T., B., Sic.
——— pisiformis, *Flem.*
——— radula, *Lamk.*
Amphidesma truncatum. (Mactra truncatum, *Turt.* Mactra, *Mont.*)
——— convexum, *Turt.*
——— declive, *Turt.* (Anatina declivis.)
Mactra Binghami, *Turt.*
——— glauca, *Born.*
——— triangula, *Brocchi.* (M. solida, *var.*) M., T., It., Sic.
Astarte Damnoniensis, *Sow.*
Venus cassina, *Linn.* B., T.
——— decussata, *Linn.*
——— dysera, *Linn.* Med., T., B., It., Sic.
——— fasciata, *Donovan*, V. paphia, *Linn.* M.
——— gallina, *Linn.* M., T. (V. cothurnix, *Duj.*)
——— pallida?
Cytherea chione, *Lamk.* M., T.
——— exoleta, *Lamk.* M., B.

Venerupis Irus, *Lamk.*
Corbula nucleus, *Lamk.* (*Syn.* C. rugosa, *Bast.*) according to Lamk. M.
——— striata, *Lamk.* B.
Pandora rostrata, *Lamk.* M., It.
Thracia pubescens, *Leach.* M., Sic.
Mya arenaria, *Linn.*
Lutraria rugosa, *Lamk.*
Psammobia vespertina, *Lamk.* M.
Solecurtus, *De Blain.* { Solen antiquatus, *Linn.* B. / —— coarctatus. Med.
Solecurtus strigilatus, *Linn.* M., B., T., Sic.
Solen ensis, *Linn.*, *Penn.* Sic.
—— legumen, *Linn.*, *Penn.* Med., B., T.
—— purpureus, *Turton.*
—— siliqua, *Linn.*, *Penn.*
Panopæa Aldrovandi (Mya glycimeris), *Mén. de la Gr.* M.
Gastrochæna hians, *Brocchi.* (Mya dubia, *Penn.*) M., B., It.
——— modiolina, *Lam.* It., Sic.

2. *Period prior to the most recent changes of relative level of land and water, and of climate.*

§ 1. *Surface-soil.*—Throughout South Devon the surface-mould partakes of the nature of the subjacent rock. The map (Pl. XLI.) illustrating this memoir will sufficiently show how many formations, composed of very different constituents, are closely associated within its limited area, so that perhaps no other district affords better opportunities for observing the influence of soil on natural vegetation, or indicates more clearly the requirements of particular plants. Geology in its application suggests various considerations, which the labourer in the pure science has too much neglected; and very many more consequences flow from the original arrangement of the mineral masses of a district than at first appear.

On the slopes of the hills of the slate district of South Devon, and immediately beneath the superficial soil, the edges of the laminæ of the slate are disturbed in a very remarkable manner, and frequently to the depth of several feet. In general, they present a simple curve, but occasionally they are most curiously contorted as in fig. 1, which represents a portion of a section at Goodrington, near Ashburton. In every case the curve is directed outwards. By the action of frost on the exposed edges of inclined slate rocks the laminæ separate, earthy matter is carried in between them, and thus the space they required is gradually increased. I have no doubt that in a similar process we have the true explanation of the appearance above described; and though it would be hazardous to say that it may not have resulted from long-continued action of the actual frosts, yet when we consider the great extent to which this separation of the leaves of the slate has been carried, and the very inconsiderable depth to which frost at present penetrates in this part of England, we seem to require a period with a lower temperature and the action of deeper searching cold.

Fig. 1.

In some places, as in most valley sections, and above the raised marine beds of the modern period, are thick accumulations of angular fragments, brought down

from the high grounds immediately above. These beds are not similar to those which in rocky districts occur at the base of cliffs and precipitous slopes; and the shape of the fragments (usually composed of flat shaly limestone as at Hope), as well as the angles presented by the surface of the accumulations, which are too small to favour the descent of fragments of even much rounder forms, oppose such an origin. The transferring of earthy matter from the sides of hills into their valleys is continually going on, and to an extent much greater than is usually supposed, but the accumulations which result from this process consist only of minutely subdivided materials; whilst those of the fragmentary beds, above noticed, seem to have required for their conveyance some agent of greater power than any at present in operation. The condition of the materials and their strictly local character sufficiently evince, that no denuding forces can have acted here; yet these accumulations rest on bare surfaces without the intervention of any mould, nor is there any mould or earthy matter mixed up with them; and it is only since they were collected, that we find proofs of disintegration by the action of meteoric agents, and traces of animal and vegetable life, of which the superficial mould is the mixed product.

Changes of Elevation and Depression.

§ 2. *Submerged forest-ground.*—Beneath the waters of a considerable portion of Tor Bay is a tract in portions of which, exposed at neap-tides, stumps of trees of large growth project above the surface, and after gales of wind have removed the sand, they are found to be firmly fixed by their roots in the soil below. This fact has been often mentioned. Leland in his Itinerary says, "Fisschar men hath divers times taken up with ther nettes in Torre Bay musens of hartes, wherby men judge that yn tymes paste it hath been forest ground," and it is also noticed by De Luc*. At Broad Sands in the same bay, a similar deposit is well exhibited between high and low water marks, passing on one side beneath the shingle of the beach, and on the other beneath the sands of the bay; and certain black beds, but for the occurrence of freshwater shells (*Cyclades*, *Paludinæ*), might easily be mistaken for an accumulation of sea-weed; the bones of deer and oxen are also readily found. These beds exactly resemble those peaty and decayed vegetable accumulations formed everywhere in low situations. Both at the Tor Abbey and Broad Sands they rest on lacustrine mud, which at the latter place contains the shells of the *Paludina impura* in great abundance; at Goodrington are likewise traces of lacustrine marl.

§ 3. *Ancient alluvia.*—An ancient forestial condition, such as even history informs us all this country presented, would necessarily occasion a greater condensation of aqueous vapour and more copious streams than now flow through this part of the county; but there are phænomena in South Devon on much too exten-

* Geol. Travels, English Trans., vol. ii. p. 303, 1811.

sive a scale to be thus accounted for. There is not perhaps a single valley through which a river, or even a brook, at present takes its course, along which alluvia are not found at elevations such as the existing streams in their most swollen states never have attained. The valleys of the Dart and the Teign afford frequent instances.

Since 1834, when I gave an account of some of the recent changes to be observed in South Devon*, facts of this kind have accumulated so rapidly, and are so generally admitted, that at present it seems necessary to give only a general indication of the nature of the evidence and of some of the localities where such phænomena may be conveniently observed.

In the valley near Chagford, and beneath the cultivated fields on each side of the stream, are thick accumulations of granitic sand and pebbles, and from their elevation and extent they prove the action of a river far more considerable than the present one. If we take the course of the Teign downwards, and attend to the sections which its banks afford, we see similar deposits of great thickness presenting that peculiar arrangement so characteristic of fluviatile action, and rising high above the reach of present floods. These deposits can be traced spreading out at the junctions of the valleys which open into that of the Teign. Another instance of the total inadequacy of the power of the present stream to produce the phænomena to be observed in its vicinity, occurs in the valley of the Lemon (a small tributary to the Teign), and particularly in that portion of it from Bickington to Holbeam Mill. The steep banks of the stream, and several good sections exposed in artificial openings in the fields show, that accumulations of the same character as those above described, occupy the whole broad expanse of level ground, and indicate the former existence of a river of corresponding width. Above Holne Bridge, north-west of Ashburton, the valley of the Dart presents similar phænomena on a wide scale †; and from this point nearly to Totness there is continuous evidence of a like kind, the neighbourhood of Staverton in particular affording most instructive instances on both sides of the river. The flat meadows about Totness are occasionally covered by the waters of the Dart, but these floods strew no coarse materials over their surface, as the fine silt and sand composing the soil sufficiently prove; so that the thick subjacent accumulation of blocks and gravel must be referred to a former condition of the river.

§ 4. *Ancient lacustrine deposits.*—Though the ancient alluvia of the Dart and Teign show that in several places their waters once spread over considerable areas, yet the only expanse which deserves to be distinguished as an ancient lake is that portion of the valley of the Teign which extends from Bovey to Kingsteignton.

The uppermost part of the series of deposits which occupies this basin, so far as the level and unintersected nature of the district exhibits, is what the clay-diggers call "the head," and it consists in some places of horizontal layers of sand, as in the upper and middle parts of the valley; coarse beds, which are often thirty feet thick, occur chiefly along the N.E. side, and it is from beneath these, that most of the pipe-clay is now raised. Good sections may be seen on each side of the lower road to Chudleigh. (Pl. XLII. fig. 8, B.) The appearances which indicate that this "head" is of fluviatile or lacustrine origin are the sub-

* See Proceedings Geol. Soc., vol. ii. p. 102.

† Mr. De la Beche, in his Report on Devon and Cornwall, gives at p. 411 a section taken at this place.

angular and flattened, rather than rounded, forms of the materials, their arrangement, and those directions of the banks of sand (which is such as may be observed in estuaries), which were caused by the currents produced in the lake by streams discharging at the same points at which they now enter the valley. The estuary of the Teign, but for artificial embankments and a wear, would even at present extend nearly as far as Teign Bridge, for the foundations of the present structure are on a level with the sea at Teignmouth. From Teign Bridge to the upper part of the valley near Bovey, there is a rise of just eighty feet; so that before that elevation took place, of which there are such numerous proofs, the whole of this basin must have been placed beneath the level of the sea.

The bones of the wild boar, the ox, and the red deer are found in the superficial sands of the Bovey valley, and beds of peat have often been discovered beneath the "head" in openings made in search for clay-beds. The bones of this lacustrine accumulation are black, with a smooth polished surface, resembling those which are now found in the beds of rivers or ponds, and are very unlike remains from breccias and caves, which are either white or slightly stained with red, and are corroded on the surface, as if they had been long exposed to the atmosphere.

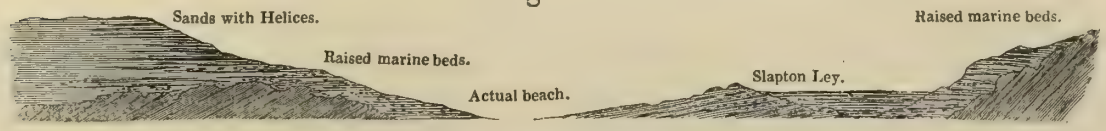
§ 5. *Raised estuaries.*—The general features of some of the valleys as they approach the sea, suggest that they were formerly estuaries, though at present only very inconsiderable streams of water flow through them; thus the broad level deposits of the valley of the Axe could hardly have been accumulated by any shiftings and expansions of the present river. Next to the eastward, the valley of the Otter presents for several miles inland a flat extent of meadow bounded by vertical cliffs (§ 1. p. 434). In some places, as from Datton Mill towards Newton, the stream flows at the base of cliffs consisting of compact beds of new red sandstone; through the greater part of its course, however, it does not approach them, but occupies a deep channel along the central line of the valley; these vertical cliffs therefore cannot possibly have been produced by any causes in present operation, and clearly indicate the extent of the former estuary. On the eastern side of the valley, below Datton Mill, is a remarkably good section, presenting three feet of silt, resting on a considerable thickness of sea-sand, the whole being placed on the coarse gravel of the district.

In the upper part of the estuary of the Exe, from Topsham to Alphington, and particularly along the western side, is a flat expanse of land, high above the present water level, but which must have been accumulated under salt or brackish water; the beds abounding with existing British species of Mactra, Tellina, Cardium, &c. These shells are found in the nursery-grounds of Messrs. Pince, as high up the valley as north of the main road leading from Alphington into Exeter. The great width of the body of water which formerly occupied this valley, is easily observed in still higher parts of its course.

The tract at the mouth of the Exe, known as the Warren, consists, on the sea side, of lines of sand-hills or dunes of some elevation, resting on a broad bank of sand and shingle of purely marine origin. This bank belongs to the time when the valley had a lower level, or was constantly submerged, and when the sea reached the base of the cliffs on the western side of the mouth of the river, and produced the range of cliffs running inland from Warren Point. As at the mouth of the Taw, where we have a like order of things on a rather larger scale, there is no real line of separation between the blown-sands and the subjacent coarse beds, which contain marine shells, so, at the mouth of the Exe, we have a passage upwards from beds purely marine into others of a fluvio-marine character, graduating into such as swarm

with the shells of two or three species of Helix. At Slapton Ley, Swanpool, and other places, are also raised marine beds passing into lacustrine ones, full of freshwater shells, which occasionally contain layers of freshwater fishes, the remains of those which from time to time are destroyed by irruptions of the sea, as in 1824 and 1836.

Fig. 2.



Raised Estuary Deposits.

§ 6. *Raised marine beds.*—A raised beech is seen a little on the inside of the point of land known as Hope's Nose, which forms the eastern limit of Tor Bay. From the rocks below, or from the sea, it has the appearance of a series of horizontal and parallel beds; and the view, fig. 3, taken from the east, shows the mass as it rests on the highly inclined edges of the limestone. (See also Pl. XLII. fig. 1.)

Fig. 3.

Raised Beach at Hope's Nose.

The distance between the usual line of high water and the lowest part of this deposit is thirty-one feet; and the thickness of the compact stratified portion is seventeen feet. How far the beach extends upwards and inland, it is difficult to determine, as it is covered by an accumulation of shaly limestone derived from the hill above; but as, at an elevation of about sixty feet, there is a bed of sharp quartzose sea-sand beneath the superficial debris, and as the point of land, previous to its elevation, must have presented a shelving coast, the marine beds would thin off gradually, and the greatest amount of elevation may be taken at about seventy feet.

This deposit is not an uniform mass throughout: in the lowest part it is coarse, and contains blocks of considerable size, and the shells of a large oyster occur in considerable numbers: higher up it becomes an exceedingly hard, fine-grained, and compact sandstone; the shells in this portion are abundant and well pre-

served, being *Patella vulgata*, *Murex erinaceus*, *Turbo littoreus*, *Turritella terebra* (*Flem.*), *Serpulæ*, *Cardium edule*, *C. tuberculatum*, *Modiola vulgaris*, *Pecten maximus*, *P. varius*, *Cyprina Islandica*, *Venerupis decussata*, and *Ostrea edulis*. The materials of these beds are such as the rocks in the immediate vicinity might supply; but chalk flints also occur, which are not to be found, that I am aware, on any beach within the Bay.

A similar marine deposit occurs on the Thatcher, a small insulated rock situated about a quarter of a mile south-west of Hope's Nose; and it is rich in shells, particularly the *Turritella terebra* (Flem.).

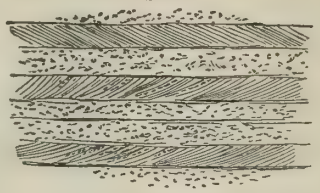
The circumstance to which the preservation of this evidence of so great a change of relative level is owing, is the hard nature of the limestone rock on which the marine beds rest, and with which they are co-extensive. From this, and also the abrupt manner in which they are cut off, these detached beds may be taken as fair illustrations of the amount of elevation, but not of their original horizontal extent.

Near Brixham, both within the Bay and between Berry Head and Sharkham Point, are similar deposits, which contain portions of the iron-lode of that place, rounded into pebbles. At one spot the hæmatite has reunited into a compact mass, and includes occasionally patches of sea-sand and shells.

Similar proofs of recent elevation occur at intervals along the southern coast, wherever the hardness of the rocks has enabled the deposit to resist the washing of the sea; as near the mouth of the Dart, and at Slapton, where it rests on new red sandstone. These beds, like those of Hope's Nose, contain chalk flints, though none are to be found along the present line of beach.

All the above deposits exhibit instances of that diagonal lamination so common in some of the older arenaceous formations, particularly in the new red sandstone of South Devon (fig. 4.). The beds also are seldom horizontal, except where the surface on which they rest happens to have been so; if otherwise, they partake of the slope, and dip at various angles towards the sea. In one instance, on the north coast of Devon, I observed an inclination of as much as 35°.

Fig. 4.



Recent marine deposits diagonally laminated.

To those who are aware how rich the waters of the neighbouring sea, and of Tor Bay in particular, are in testacea, the list above given will appear exceedingly meagre; but in this respect the Devonshire deposits agree with those of the same period in other localities. Not only are all the forms which have been already noticed, and which may be considered as the present characteristics of our south-western coasts, entirely wanting, but we miss all those other shells which any beach, at the present day, would readily supply. This is only negative evidence, but it suggests that the period of these raised deposits may have been one less favourable than the present to the development of marine life,—owing, perhaps, to a lower temperature; such as the broken up or detrital edges of the slate rocks would also indicate.

Tertiary Deposits.

Period marked by Extinct Animal Forms. (Map, Pl. XLI.)

§ 1. *Gravel.*—This term would probably be applied to many accumulations within the district here described, which, though they may have been produced by

a similar condition of things, yet belong to very distinct periods; it is used, in the present instance, to designate those deposits which have been found to contain certain mammalian remains.

All the valleys of South Devon, from the Exe eastward as far as Lyme inclusive, have afforded the tusks, bones and teeth of the elephant and rhinoceros. The deposits which contain these remains, though not stratified, have a very distinct horizontal arrangement, consisting of gravel, with irregular layers of sand, and they afford sections similar to those which estuary or fluviatile accumulations usually present. They occur invariably in low situations, proving that, prior to the occupation of the country by the animals in question, the several valleys were as deep as they now are, that the process of excavation had been completed, and that the surface exhibited the same outline as at present.

This period may be contemporaneous with, or immediately subsequent to, that of the occupation of the ossiferous caves; and in the latter case it would be synchronous with that inundation which seems to be requisite to account for all the appearances presented by the ossiferous fissures, and which will be presently mentioned.

Comparing the remains of the large Pachyderms found in caves with those of the gravel beds, the latter appear to have generally belonged to old, full-grown animals, whilst collections from Kent's Cavern show that the animals were mostly young.

Referable also to this period are those accumulations which, at the western base of Haldon, either fill the wide fissures in the lime rocks, or are collected in depressions on their uneven surfaces; the latter containing the remains of all the animals found in the fissures, as may be constantly seen at the great quarry near Chudleigh, whenever the workmen remove the "head" to get at the surface of the limestone*.

§ 2. *Ossiferous caves and fissures.*—The phænomena of ossiferous caves, fissures and breccias have been usually classed together, but they appear to me to be really distinct, both as to time and the circumstances which produced them.

Their natural order appears to be, 1st, the caves which have been inhabited by animals; as Kent's Hole, Anstis, and Yealmpton, described by Col. Mudge†. 2ndly, a complex group, including all those breccias or superficial collections of angular fragments usually found in the neighbourhood of calcareous strata, frequently associated with the bones of animals, and which seem also to have required the aid of moving water to have reached their present positions; and 3rdly, the large fissures in lime-rocks, as those of Chudleigh and Plymouth, now filled to their mouths with ossiferous breccias, but often expanded into chambers containing masses of mud, bones and debris, the forms and positions of the accumulations clearly pointing to the vertical fissure through which they were introduced. Confirmation of this process of filling is afforded by many limestone caverns which have not been found to contain any remains of animals; such caves having the character of fissures, and must not be confounded with the inhabited ones. In filling the fissures the transporting power of currents of water is required, which

* The collection of bones of extinct animals found in a depression in the limestone of the Hoe, and which Dr. Moore brought before the Geological Section of the meeting of the British Association at Plymouth in 1841, were most probably from a similar superficial accumulation.—(*Note*, 1841.)

† Geol. Proceedings, vol. ii. p. 399, 1836.

could move along from exposed surfaces all loose materials, bones, and land-shells, and which would naturally fall into such open chasms. Nor is this action of flowing water a mere assumption; whoever will examine the collection of materials in these great open joints and fractures will be satisfied that they could have been filled only in the manner here suggested; there being in every case an admixture of materials from a distance, and it is a remarkable fact that these have been derived from rocks *in situ*, north of the places in which we find them. Thus the breccias of Chudleigh contain granite and altered rocks from the sides of Dartmoor, and the same phænomenon occurs at Yealmpton and Plymouth.

The first class of caves, such as those near Torquay and others, belong to the time when the country was the actual habitation of certain forms of animals now extinct or foreign; the second class contain the evidences of some subsequent event, which apparently happened at the close of that period.

The well-known Kent's Hole, near Torquay, is a large cavern in a compact limestone, and consists of one large chamber, with several minor ones communicating by narrow passages, all parts being of easy access. A stalagmitic crust, which appears to have covered all the lower part of the cave before it was broken up in the search after remains, is still very thick in some places, and it is a curious fact that the deposition of stalagmite has been subsequent to the introduction of the clay, for I have frequently worked through the entire thickness of the latter and found it resting on the bare limestone. No increase to the stalagmite is now being made. The mass of bones which this cave contained was very great, and must have required a considerable lapse of time for its collection; there are appearances also about many of these remains which seem to indicate that they had been long exposed to the air before they were included in the clay. Nearly all the specimens I possess from this cave bear the marks of teeth, and mixed with them are quantities of the fæces of animals which must have fed largely on bone. Human remains and works of art, such as arrow-heads and knives of flint, occur in all parts of the cave and throughout the entire thickness of the clay: and no distinction founded on condition, distribution, or relative position can be observed, whereby the human can be separated from the other reliquiæ.

The obvious inference from this fact is at variance with the opinions generally received, and the circumstance of the Paviland Cave will doubtless be adduced as a solution of the difficulty. The two cases have nevertheless nothing in common. In the Paviland Cave the bones of the skeleton were together, in their mutual relations, and the several implements in close juxta-position; in the other they are as above described, and there is not a single appearance which can suggest that the cave has been used as a place of sepulture.

The bones of the cave must have been gradually collected; the clay may either have been carried in at some given period, or else have been added from time to time by floods; in the latter case there would be an alternation of layers of bones with seams of clay, but we find no arrangement of the kind, and I think it more probable that their confused mixture has resulted from some one event.

The osseous remains found in Kent's Cave belong principally to the elephant, rhinoceros, ox, deer, horse, bear, hyæna, and a feline animal of large size*.

This and other similar caves, both in England and on the continent of Europe, as the celebrated Kirkdale

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* The following observations respecting the animals which occupied osseous caves were read March 25, 1840.

Cave, described by Dr. Buckland, are supposed to have been the dens of hyænas. There can be little doubt that the bones found in these caves have been collected by animals of prey, and as all the forms we find in them are such as we are acquainted with at the present day, the argument from analogy is the most obvious. If we take as our guide the habits of existing species of hyænas, we find little or nothing to warrant the conclusion that they have been the active agents in conveying the cave-bones into the places where we at present find them. These animals, now much better known than formerly, neither hunt after living prey nor live together in packs, still less in caves*; nor have they courage to attack any formidable animal; on the contrary, such is not the position of the genus in the natural order to which it belongs; they prefer the putrid flesh and bones of such animals as they find in their nightly prowlings. The instance quoted by Dr. Buckland, on the authority of Burchell, in support of the supposition that these ancient hyænas were hunting animals, is now well known to have rested on the false classification of the *Hyæna venatica* of Burchell† with the true hyænas, an animal in important parts of its structure related to the genus *Canis*, and with which it has many similar habits; but even granting that these ancient hyænas might have acted in concert, and thus attacked such large animals as the elephant and rhinoceros and subdued them, they could never have conveyed their bodies over the surface of a rocky limestone district; and on the authority of Knox we may assert, that they never attempt to do so—whatever an hyæna meets with he devours greedily on the spot.

Lions and panthers, on the other hand, pursue only living prey, which at one spring they lay prostrate beneath them, and securing it in their jaws, and bearing its weight on their powerful shoulders, they retreat with it to their caves. Cuvier notices the extraordinary strength and rapidity of the movements of the larger Felidæ. In Asia there is no animal which they are afraid to attack; the African lions constantly carry away oxen and animals of great bulk. With respect to their usual abodes, we have the authority of all African travellers and hunters, that chasms, caves, overhanging ledges of rocks, and similarly protected places are their haunts, and the spots to which they carry their prey.

Large Felidæ existed in South Devon, in other parts of England, and Northern Europe during the geological period we are now considering; their remains occur in the Oreston breccia and in Kent's Cave. Dr. Buckland has figured both a canine and a molar tooth from Kirkdale. "Ces dents," says Cuvier, "n'ont rien de différent de celles d'un lion, même pour la grandeur." (Oss. Foss., 3rd edit. t. iv. p. 455.)

I conclude, from the known habits and powers of the only ten genera we have to consider, that the various animals were dragged into the caverns by powerful Felinæ, who used these places as dens during a long period of time; that when the larger Carnivora had satiated their hunger or were absent, the caves were visited by hyænas (who lived then as now on the abandoned prey of others), by whom the bones were picked, gnawed, splintered, and scattered. The hyænas who frequented the caves would in this manner be exposed, even more frequently than any other animals, to fall a prey, and accordingly their skulls are found pierced by the canine tooth of a large animal; and in these instances their remains would be devoured by their own species: that such was the case, the bones of the hyænas sufficiently show.

The occurrence of human remains and works of art in Kent's Cave deserves some further notice, such a statement being very liable either to be questioned, as at variance with a favourite theory, or to be so accounted for as to present no difficulty in the way of the theory. There is no *à priori* reason why man and the several animals whose remains occur in caves and in gravel should not have lived here at

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* "Les hyènes se tiennent solitaires dans les parties montagneuses."—Cuv. Oss. Foss., 3rd edit. t. iv. p. 387.

† "Il est évident que cette hyène [*H. venatica*] doit former un sous-genre dans le genre des chiens, qu'il liera plus intimement à celui des hyènes."—Cuv. Oss. Foss., edit. 1825, t. iv. p. 387; Règne Animal, vol. i.; Swainson, Class. of Quadrupeds, p. 131.

some remote time, just as closely allied species now do in other regions: that some of the fossil species may differ slightly from existing ones does not affect the question, as the man of that period may have differed as much, or belonged to a more southern type. Few, I imagine, who are acquainted with the facts which the labours of MM. Schmerling, Marcel de Serres, and others have established, entertain any doubts as to the fact that the bones of man have been found in caves; what I wish to state distinctly is, that they occur in Kent's Cave under precisely the same conditions as the bones of all the other animals. The value of such a statement must rest on the care with which a collector may have explored; I must therefore state that my own researches were constantly conducted in parts of the cave which had never been disturbed, and in every instance the bones were procured from beneath a thick covering of stalagmite; so far then, the bones and works of man must have been introduced into the cave before the flooring of stalagmite had been formed. It may be suggested, that this cave was used as a place of sepulture by some early inhabitants of this country, and that bones of the other animals occupied the lower parts of the cave when such sepulture took place.

In this case our researches should expose the human skeletons entire, as in the Paviland Cave; or at least the bones should occur in some sort of mutual relation to each other, but no such thing has ever been observed by any explorer in Kent's Hole; so that as far as the evidence from this cave is to be our guide (and which is all that we should look to), there is no ground why we should separate man from that period, and those accidents, when and by which the cave was filled.

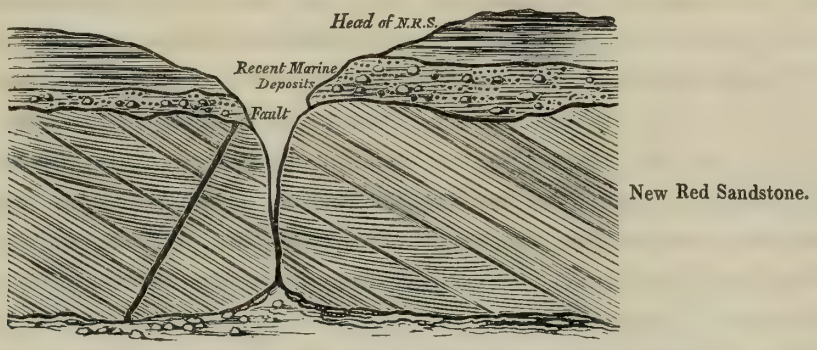
The favourite habitats of beasts of prey, in a wild state, are warm and dry situations; and at the time when, as we may fairly assume, the country was thickly covered with forests and swamps—the range of the horse, the ox, and the large Pachyderms,—we cannot well imagine spots better suited to Carnivora than the great tabular masses of limestone, with their caves and crevices, which the surface of South Devon presented. It would be to such spots that they would retreat with their prey. So that in the lapse of time the surfaces would be strewed with the teeth and harder portions of every animal of the country and period; just as, according to all accounts, the vicinity of the haunts of the large Carnivora is at the present day. Any subsequent inundation, such as that which other considerations have established, would carry forward with it all the animal remains, and leave them, together with detached blocks of limestone, mud, sand, and foreign rocks, in every open chasm and depression.

In support of this there are evident marks about most of the bones from the osseous breccias, that they had long been exposed to the air before they were buried in the clay. Had all the various animals whose bones have been collected, fallen into these chasms, portions of each animal should occur, and in nearly their proper relations; but there has never been observed the slightest tendency to such a condition. Very little personal search among these masses of breccia will be sufficient to convince any observer, that casualties of this sort cannot account for the scattered fragments of bone he may discover in them. Animals may have so perished; but such cases must be considered exceptions to the process by which the fissures were filled.

§ 3. *Surface-accumulations at higher levels.*—Over most parts of the district here described, particularly within the combes of the new red sandstone series, are thick accumulations of local debris, as if during the formation of the valleys the finer particles had been removed and the coarser alone left. In the Dawlish valley, associated with materials from the new red conglomerate strata, are others derived from the cretaceous series, the whole mass being upwards of forty feet thick (Pl. XLII. fig. 5.). Similar accumulations are scattered over the whole of that part of Devon which intervenes between the Haldons and Blackdowns; and those in the valley of the Otter present as great an admixture as the deposits of Dawlish; but proceeding eastward, as in

the valley of the Sid, Salcombe, Weston, and Branscombe, the collection consists of chalk-flints, flint-breccia and sandstone, and materials from the harder beds of the greensand. These accumulations are not confined to valleys, but invest the slopes and crown the summits of many minor ridges, as those which lead up to the Haldons. In thus classing together the accumulations on the high grounds with those in the bottoms of valleys, it is not implied that they are exactly of the same geological age, or referable to some particular period of dispersion, but that they are the results of those agents, which, for a long period, must have been in operation over this district, and produced the actual configuration of surface.

Fig. 5.



Section near Dawlish of regenerated new red sand resting on a recent marine deposit.

The above cut represents a road-section near the summit of the hill west of Dawlish. A bed of marine debris rests on the uneven surface of the new red sandstone, and above it, is a thick mass of regenerated new red sand, in regular layers, but without a single pebble of chert or flint, and the uppermost mass is another thick bed of debris.

In the cliffs east of Dawlish is a similar thick deposit of pure, regenerated new red sand, resting on a bed of materials from the chalk and greensand series.

§ 4. *Uppermost beds of Haldon.*—The outline of the Haldon and Blackdown hills, viewed from any point which commands their range, is strikingly horizontal, and their upper surfaces present table-lands, from which deep combes and valleys, descending to the level of the sea, have been excavated through various formations. The uppermost deposits, of inconsiderable thickness in both ranges, correspond; but in the nature and condition of their materials they are very distinct from what occurs immediately beneath them. The line of contact presents an irregular surface, similar to that exhibited where the subjacent beds rest on chalk or greensand.

This superficial accumulation consists principally of flints, but it contains in places, and rather plentifully, fragments of red porphyry, altered slates, black schorly granite and quartz, from Dartmoor; all the latter being rounded, like marine shingle, and the whole mass having an exceedingly water-worn character. (Pl. XLII.

fig. 8 A.) The proportion which the crystalline rocks of the upper Blackdown beds bear to the rest, is less than in the equivalent ones of Haldon, but the pebbles are mineralogically identical, and undoubtedly have been derived from the same quarter.

In these beds we seem to have the last operation in the order of events, before the excavation of the deep valleys of the district commenced.

A bed of considerable thickness, composed chiefly of angular chalk flints, but containing in its lower portions large tabular and angular blocks of chert and sandstone, mixed with sand, is found on Blackdown and its ramifications, resting occasionally on chalk, but more generally, as on Haldon and Milber Down (Pl. XLI.), on greensand. This accumulation lies on a very uneven surface, as is well exhibited along the coast-section generally, both east and west of Sidmouth ; the depressions which produce this rugged outline being either troughs, or deep, inverted cones. In 1836 I examined one of the latter, which had been just emptied of the flints it had contained. The strata in which it occurred, were of very compact sandstone, and the sides of the pit, which was circular, exhibited deep concentric grooves, such as would be produced by the circular motion of the materials within. Similar pits have been often noticed over the surface of the chalk, and they are very common in this neighbourhood. They have been attributed to the erosive action of acidulous waters ; but as they are not confined to calcareous beds, extending here into arenaceous strata, such an explanation can hardly be received as a general mode of operation, and we must have recourse to the mechanical action of hard substances set in motion by water, in the same manner as pits and basins are now constantly produced along the coast and in rapid rivers. This mass of purely cretaceous materials, the flints, coated by a black substance, being intermixed with abundance of strong clay, is very distinct as an accumulation from the overlying water-worn flints and pebbles of older rocks ; but it corresponds exactly with those beds which in many places constitute the lowest tertiary deposits, where they rest on chalk. In the Bovey valley a similar accumulation is subjacent to the pipeclay beds.

Other portions of the tertiary series apparently once extended here. Scattered largely over the surface of all this district, and mixed with the debris on the hills, are blocks of a breccia, composed of angular fragments of chalk flints, cemented together by an exceedingly hard, siliceous paste. This breccia affords proof of a long post-cretaceous period of tranquil deposition, and of a subsequent one of destruction, of both of which it is the sole remaining indication. Besides the breccia, there are large slabs, composed partly of similar materials, and in part (taking the blocks according to their thickness) of a compact, fine-grained sandstone, some blocks containing only an occasional flint, but some none at all, in which cases they are mineralogical grey-wether sandstones ; and may probably be the equivalents of those siliceous masses, warranting, a presumption at least, that tertiary

deposits once extended wherever this breccia now occurs; for the blocks are so angular that they cannot be supposed to have been conveyed from a distance. The breccia, with its accompanying sandstones, occurs on the Blackdowns; it is very abundant in the valleys about Sidmouth; it has been worn into rounded boulders and pebbles in the great valley of the Exe; it is found again in tabular masses on the Haldons, below the accumulation of more rounded materials (p. 448), and in similar angular blocks beneath the pipeclay. A very large block serves as a foot-bridge over a water-course near Kingsteignton *.

SECONDARY DEPOSITS. (Map, Pl. XLI. Sect. Pl. XLII. Figs. 1, 2, 3, 5, 8 A.)

§ 1. *Chalk.*—There are the following proofs that the chalk extended over portions of South Devon, from which it has been since removed: 1st, in the abundance of chalk-flints, uninjured by transport or attrition, which crown the greensand hills of Haldon (fig. 8 A.); and 2ndly, in the circumstance that the high lands along the line of coast, from the Exe westward, present a very uniform elevation, the dip of the beds being in the same direction, and at such angles, that, proceeding from west to east, we encounter a constantly ascending series, and find the various divisions smoothed off, as they rise to the general surface-line of the country.

The chalk in the valley of Beer offers the same artificial divisions which it does in the South Downs, the only difference worth noticing being, that the cretaceous series generally in its extension westward must have presented, when complete, a gradually decreasing thickness. With the slight difference of a rather larger proportion of siliceous particles, the chalk seems to have preserved its general appearance as far westward as the small overlying mass on Maynard Hill, where it is very remarkable on account of its great abundance of the remains of Radiaria. Blocks of chalk may be found among the debris as far west as Peak Hill, near Sidmouth, and the thick capping of angular flints on the greensand of Haldon, as before stated, and on that of the Bovey valley, indicate that the formation once extended thus far.

Certain white granular beds, worn into deep furrows on the upper surface, which surmount the greensand at Staple Hill, near Stover, and contain the spines of a *Cidaris*, may perhaps represent chalk. (Pl. XLII. fig. 2.)

§ 2. *Greensand.*—The greensand of the S.E. parts of Devon may be considered as belonging to the great mass of Blackdown, so well described and illustrated in Dr. Fitton's memoir†. An interesting fact, which appears to have escaped observation, is the occurrence of a shingle bed in the lower part of the deposit, and well seen in the capping of greensand on Salcombe Hill, near Sidmouth. The pebbles consist of

* See an account of similar blocks in Dorsetshire in the Memoir of Dr. Buckland and Mr. De la Beche on Weymouth, Geol. Trans., 2nd Series, vol. iv. p. 4.

† Geol. Trans., 2nd Series, vol. iv. p. 235.

compact sandstone, containing green earth, and are totally unlike any of the older English strata; but they are exactly such as occur on the beach near Swanage, and derived from the harder beds of the greensand. I was unable to find a specimen containing organic remains. If, as most geologists, I feel confident, will admit, these pebbles have been derived from greensand beds, just as pebbles of the hard compact sandstones of the raised marine beds on the actual coast may be included in strata now being formed, we have proof that portions of the greensand series had become consolidated, and having been exposed to destruction, had contributed materials to the shingle beds in question; or if this mass of shingle has been derived from some older formation, as for instance, from some beds of the oolitic series, the mineralogical agreement between the shingle and the overlying sand would follow as a natural consequence, just as the recomposed tertiary greensand beds cannot be distinguished from the parent subcretaceous strata. Exogyræ and Serpulæ adhere to the pebbles. A host of the Blackdown fossils given in Dr. Fitton's tables * are found in the branches of the formation which extend to the sea-coast. East of Sidmouth large branched corals are very abundant, and a gigantic, undescribed Ostrea.

The next mass westward is that of High Peak, and traces of the deposit perhaps occur on the Woodbury Hills, near the Belvidere.

The greensand of Haldon differs a little from that of the Blackdowns. The lower beds, which rest on new red sandstone (fig. 8 A.) and carbonaceous rocks, consist of clay and yellow sand, with fragments of shells, or else of a pebbly conglomerate, made up of portions of the carbonaceous series, with shells and large corals†. This conglomerate may be found along the western slopes of Little Haldon. Sands with abundance of green earth, layers of whetstone, and beds of shells of considerable horizontal extent and thickness, converted into red or transparent chalcedony, form the middle portion. Above these are sands with no green earth and lines of chert. A very distinct vegetation everywhere marks the line of junction.

To the westward of the Haldons the greensand has not been described by former observers, yet it occurs in situations which make it exceedingly interesting, and renders a detailed description the more necessary, as it illustrates some of the disturbances which the district has experienced.

One great mass is that of Milber Down, near Newton Bushel, where, owing to the thick accumulation of sand and flints which forms the upper surface, and the few places in which unequivocal stratified beds are exposed beneath, the tract has been usually considered a portion of the Bovey basin. The Milber beds are identical with those of Haldon, and but for the roads, which in Haldon have exposed artificial sections, proof of undisturbed greensand would be as difficult on one eminence as on the other. Along the edges of the waste of Milber, as in the descent to Haccombe, however, are beds of true greensand, with included layers of chert and whetstone, covered with characteristic fossils. From that place the

* Geol. Trans., 2nd Series, vol. iv. part 2. p. 239.

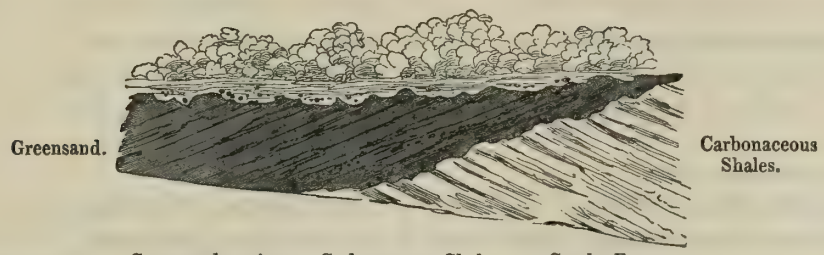
† Mr. Lonsdale I find refers these to Ehrenberg's genus Cyathina.

deposit ranges over the summits of the hills above Coffinswell, passes into the valley a little below Kingskerswell, and then rises into the opposite hills; near Aller Mills it contains beds of yellow ochre, with sand and light-coloured clay—an association very like that at Shotover; and it crowns the hills above Woolborough. On the other side of Newton it forms very compact beds a little beyond White Hill, beneath clay and debris, and also at Ringslade. From Staple Hill (fig. 2.) to the Ashburton road the greensand acquires considerable breadth, the strata dip at a high angle, and appear broken: intermediate between the greensand and the "head" are the white beds, which may perhaps represent chalk.

The *Trigoniæ* which occur in the arenaceous beds at Staple Hill, prove the deposit to belong without any doubt to the greensand.

Crossing over to the opposite side of the valley, similar beds are well exposed by Bellamarsh. On each side of the road leading down to Combe Farm, we have an artificial section, fig. 6, showing the base of the deposit, resting on carbonaceous shales, and containing fragments of culmiferous grit, also Exogyræ, *Pecten quinquecostatus*, &c. in great abundance.

Fig. 6.



Greensand resting on Carbonaceous Shale, near Combe Farm.

Below Ponswine Farm the formation presents fine-grained beds with green earth and numerous characteristic fossils. The deep cutting for the new road affords a good section, showing the thick capping of debris resting on the furrowed surface of the greensand: in this section are lines of chert, and some very remarkable beds almost entirely composed of Orbitolites.

The greensand along all this course occupies the slopes of the hills which form the Bovey valley, and it rests on new red, carbonaceous, and transition strata, perhaps upon granite, as near Letford Bridge, on the road to Lustleigh.

Pipeclay occurs towards the base of the greensand in Great and Little Haldon *, and attempts have been made to work it near the western extremity of Great Haldon. In a deep water-course below Woolborough, pipeclay beds alternate with sand, and an alteration of the road near Ford presented an interesting section of similar clay-beds alternating with greensand.

A small outlying patch of greensand occurs near Larcombe Bridge, below Ideford, a connecting link between the Haldon deposits and those of the Bovey valley.

* It is the bed in the section presented by a well, carried through the entire thickness of the deposit by Sir Robert Newman, quoted by Mr. De la Beche, Report, p. 247.

Scattered over the surface of the soil about Lindridge, near Ideford, are large blocks of a compact siliceous rock, containing much green earth, and many well-preserved greensand fossils; they also include rounded pebbles from the harder beds of the carbonaceous series. These blocks occur only at this particular spot, which is just below the point where a mass of trap (certainly of subsequent date to the new red sandstone) is hid by the greensand of Haldon; they are unlike any of the beds to be found in place on either of the Haldons; and judging from the change which the trap has effected in beds of new red sandstone, these masses present just such a character as would have been produced by the igneous rock had it come in contact with the lower greensand, which probably was the case.

The greensand beds of the Haldons and the Bovey valley are very far from containing the same number of species of shells as the Blackdown; I have, however, collected the following species:—

Exogyra halyotoïdea, *Sow. Min. Con.*
——— conica, *Sow. ibid.*
Pecten asper, *Lam. Anim. sans Vertèb.*
——— quinquecostatus, *Sow. Min. Con.*
——— quadricostatus, *Sow. ibid.*
——— Stutchburianus, *Sow. Geol. Trans.* 2 Ser. vol. iv.
Lima semisulcata, *Sow. ibid.*
——— proboscidia, *Sow.* Ponswine.
Inoceramus concentricus, *Parkin. Geol. Trans.* 1 Ser. vol. v. Ponswine; Staple Hill.
——— gryphæoides, *Sow. Min. Con.*
——— mytiloides, *Mant. Geol. South Downs.*
Gervillia aviculoides, *Sow. Min. Con.*
——— solenoides, *Defrance, Dict. Sci. Nat.*
Trigonia aliformis, *Sow. Min. Con.*
——— spectabilis, *Sow. ibid.*
——— scabra, *Lam. Envir. de Paris.*
——— dædalia, *Park. Org. Rem.*
——— excentrica, *Park. ibid.*
Pectunculus umbonatus, *Sow. Min. Con.*
Pectunculus sublævis, *Sow. Min. Con.*
Cucullæa carinata, *Sow. ibid.*
——— glabra, *Sow. ibid.*
——— fibrosa, *Sow. ibid.*
Cardium Hillanum, *Sow. ibid.*
——— proboscideum, *Sow. ibid.*
Venus angulata, *Sow. ibid.*
——— gigantea.
——— lineolata, *Sow. Min. Con.*
——— caperata, *Sow. ibid.*
——— sublævis, *Sow. Geol. Trans.* 2 Ser. vol. iv.
Tellina inæqualis, *Sow. Min. Con.*
——— striatula, *Sow. ibid.*
Mya læviuscula, *Sow. Geol. Trans.* 2 Ser. vol. iv.
——— mandibula, *Sow. Min. Con.*

Auricula incrassata, r. *Sow. ibid.*
Littorina pungens, *Sow. Geol. Trans.* 2 Ser. vol. iv.
Turritella, n.s., r.

Serpula filiformis, *Sow.** *Geol. Trans.* 2 Ser. vol. iv.

Remarkable differences are observable in the above suite, when compared with that contained in the rich fossiliferous sand of the hills about Sidmouth, not only in the species but in the condition in which they occur. At the latter place, as already described, are beds of shingle, with Serpulæ and large oysters, apparently in the very places they occupied when living, surmounted by beds with the various Blackdown species enumerated by Dr. Fitton, facts which would indicate an increasing depth of

* The corals of the greensand of England have not been described: none are enumerated in Dr. Fitton's valuable table. Large branched Cyathophylla abound in the greensand of Sidmouth; they are numerous in that of Haldon, together with *Astrea elegans, A. escharoides, Retepora clathrata, Eschara.*

water over that particular spot. The mollusca so abundant there, are altogether wanting in the Haldon beds, which contain conchifera of littoral habits, mostly broken and water-worn. Nor, in a very large collection have I a single specimen with the valves united, and very few even perfect.

The greensand beds of the Bovey valley, owing to their covered condition, have as yet afforded fossils from only a few localities, indicated in the foregoing table, and the species are few in number. The Orbitolites, which occur sparingly on Haldon, are exceedingly numerous in beds below Lindridge Hill, forming by themselves layers of some thickness; the same beds contain Orbiculæ.

§ 3. *The New Red Sandstone.*—This formation presents, in a direction from east to west (see map, Pl. XLI.), the following obvious divisions :—

1st, Marls, containing gypsum in the lines of deposition ; and extending as far as Sidmouth.

2ndly, Sandstones, as between Sidmouth and Dawlish.

3rdly, Shingle and conglomerate.

It is almost unnecessary to observe, that these divisions are not separated by any distinct lines, but that they gradually pass into each other. In general the conglomerate increases in coarseness towards the western edge of the deposit.

This formation has been so fully described in the "Outlines of the Geology of England and Wales," Chapter IV., that a few observations as to the mode of its accumulation is all that it seems to require here.

The rocks which supplied materials for the formation of the conglomerate, are mostly such as are found in the immediate district, consisting of slate, limestone, porphyry, carbonaceous grit, greenstone-trap, and altered shales. Some of the blocks are much water-worn, as the limestones generally towards the edge of the deposit; but taken within its area, as in the cliffs of Teignmouth, they are subangular. It will be found too, that along the boundary-line the conglomerate partakes of the nature of the rocks in the immediate vicinity; as for instance, limestone blocks predominate in the beds facing Marychurch, Barton, Kingskerswell, &c., a circumstance in strict accordance with what was noticed respecting the present sea-beach. In some more central places, on the other hand, the body of water which distributed these conglomerates appears to have set in a constant direction; for the blocks of porphyry, which, from similarity of character, must have been derived from one source, have a linear arrangement, as may be seen along the Haldons, especially up the Combe Valley; and, tracing this line down to the sea, we find them occupying the whole vertical thickness of a lofty cliff east of Teignmouth. From the inspection of a very large collection of specimens, I feel confident that these blocks have been derived from the great sheet of porphyritic matter, of which portions still remain, *in situ*, at the north extremity of Great Haldon and other places ; so that we are moreover informed as to the direction in which the materials moved, and the prevailing set of the water which transported them, just in the same manner as we now find oolitic rocks travelling eastward, and mixing with the chalk-flint shingle of the coast of Sussex, but know, that we never meet with a single fragment of that series mixed with the older materials on the beaches or bed of the sea to the west. If the conjecture be correct as to the source from which the porphyritic blocks were derived, from the known fact that they occur in particular places throughout the entire thickness of the deposit, as in the cliff already noticed, we arrive at another unavoidable inference, —that some portion of the porphyritic mass was not covered up, but was so situated as to be exposed to constant destruction throughout the red sandstone period; whilst it will be seen, in the notice of this

porphyry, that in other places, after having supplied some materials, it became buried under the sandstone. We thus appear to have ascertained, for one point at least, the limit of the waters of that particular period. Other considerations would seem to point out, that in some places the existing limits are nearly the original ones, such as the gradually decreasing thickness of the sandstone beds westward; the local character of the deposit in some places already noticed; the manner in which it terminates abruptly at the base of limestone cliffs, as near Wotton; and where it follows depressions caused by old disturbances in the slate rocks, as at Bowbridge.

This formation is distinctly stratified throughout, and it is well known that from Babbacombe to Sidmouth, a distance of twenty miles, the sea-cliffs are entirely composed of it, and that it finally disappears beneath newer formations a little beyond Axmouth, about nine miles farther east. Along all this line the strata dip at a slight angle towards the S.S.E.; in one place only, on the south side of the Teign, is the inclination reversed, and for a short space the beds are horizontal. Now if we suppose, as has been done, that the order of conglomerates, sandstones and marls is constant throughout this formation, the one carried beneath the other with the same relative dimensions that may be observed in any given section, and if we attempt to estimate the total thickness of the deposit, deduced from the mean angle of its dip, we obtain a result which at once shows that such a supposition must be erroneous, viz. a thickness of little less than five miles for the deposit at Axmouth.

There is no reason why the divisions of the new red sandstone should be considered as members of an ascending series, although the sandstones seem to overlie the conglomerates, and in turn to be covered by the marls, as, in so doing, we tacitly admit a mode of accumulation very different from that which is at present effected by large bodies of water. Successive additions now take place, as we have seen (p. 435), over every part of the bed of the sea simultaneously, wherever particles of matter are carried; and the distribution of the conglomerates, sandstones and marls, the finer sediment occurring at the greatest distance from the western boundary of the formation, show us the manner in which the deposition of the whole series could proceed contemporaneously.

If we take the coarseness of the conglomerate as a measure of the forces which produced it, and compare it with the effects of the action of the waves of the actual sea upon the very same mineral masses, we shall see no reason to call in the aid "of a stormy and disturbed period, agitated by perpetual convulsions." Such a state of things could never have existed. All the laws by which the stability of large masses of water are maintained must have been in operation during every period,—waves, propagated by whatever cause, must have had their limits confined by the same laws as regulate them now; nor is a contrary supposition at all necessary, as no masses occur in the new red conglomerate which exceed in size such as, during every gale, are removed by the waves on our own coasts. The largest porphyritic blocks which fall from the cliffs east of Teignmouth are soon transported away; and the conglomerate of the raised marine beds of Hope's Nose is as coarse as any that occurs in the new red conglomerate series: beds of conglomerate, of whatever age, indicate the action of breakers and an inconsiderable depth of water.

The arenaceous beds of this series, as west of Sidmouth, present ripple-markings on their upper surfaces, and this beneath 200 feet of the deposit in a vertical line. It has been supposed that these markings may be produced under any depth of water, but perhaps erroneously, from the well-known tranquillity which prevails over the bed of the sea, even at the inconsiderable depths to which divers have descended; the castings of worms are also beautifully preserved over the same slabs of sandstone,—a circumstance, coupled with the former, which would seem to indicate that a gradual encroachment of the sea, or a slow subsidence of its bed, accompanied the accumulation of the deposit in this part of England.

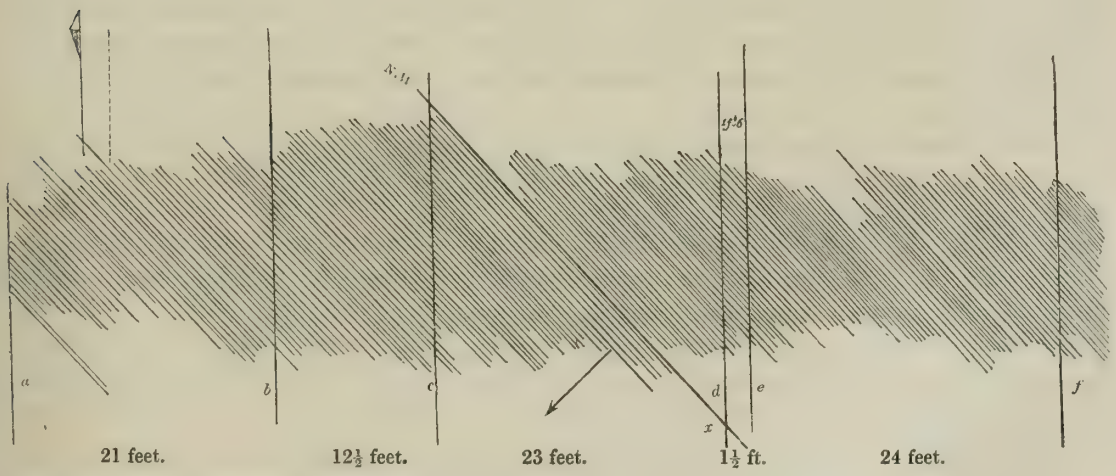
The bright red colour of the formation, particularly the South Devon portion of it, has not been satisfactorily accounted for. The colouring metals are iron and

manganese, but the latter only in a small proportion; and it may be some help towards the solution of this point to mention, that wherever limestone blocks and pebbles occur (as about Teignmouth), the materials which surround them are not coloured. Now either the whole mass was red throughout, and the colour of the portions in contact with the limestone subsequently discharged, or the colour must have been at some time subsequent to the accumulation of the deposit imparted to all the mass, except to such portions as happened to be in contact with fragments of limestone; the latter supposition seems most reasonable. If we examine the coloured portions, we observe that each particle is coated with a thin pellicle of peroxide of iron: now as this could not have been held in solution by the water which collected the materials, we must suppose that the conditions under which they were subsequently placed, favoured the conversion of the iron contained in the abraded porphyritic rocks, and at first only mechanically disseminated throughout the mass, into colouring matter for the whole of it, with the exception already noticed.

A jointed structure, the joints having a constant direction, is not distinctly marked throughout all portions of this formation, and the nature of the deposit does not admit of its being observed as easily as in some other rocks; yet lines belonging to a system of joints may occasionally be traced even among the conglomerates, as beneath the Ness at Teignmouth.

Near Sidmouth these divisional lines are particularly well marked, and may serve as a general illustration.

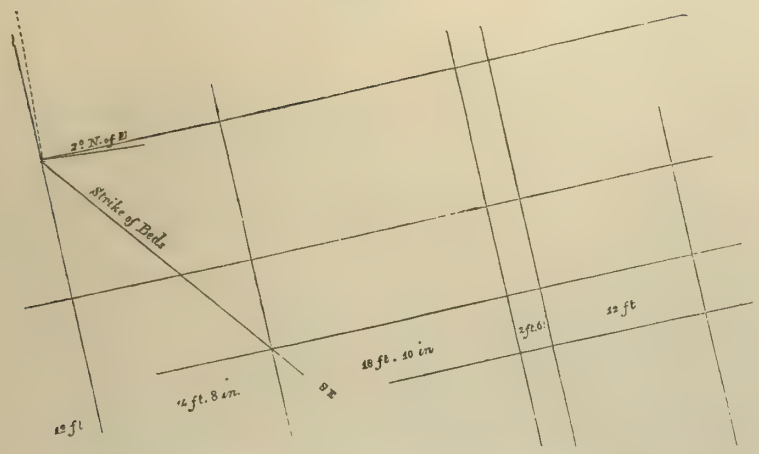
Fig. 7.



Jointed and Cleavage Structure, New Red Sandstone near Sidmouth.

The above diagram represents a ground-plan of rocks of fine-grained fissile sandstone, exposed at low water, and exhibits six lines of joints (*a* to *f*), ranging 1° 30′ west of true north, at intervals of 21 ft., 12 ft. 6 in., 23 ft., 1 ft. 6 in., and 24 ft. The strike of the beds is marked by a seam of sulphate of lime *x*, running N.W. and S.E., and the other lines parallel to this are those of the partings of the laminæ.

Fig. 8.



Jointed structure, New Red Sandstone near Sidmouth.

Fig. 8. represents the north and south joints, at the intervals of 12 ft., 14 ft. 8 in., 18 ft. 10 in., 2 ft. 6 in., and 12 ft. These two plans, taken only a short distance apart, give the divisional structure of the deposit. Now the dip of the beds is N.E., but from the direction of the coast at this particular place, the east inclination only is seen, and consequently only one set of joints, viz. the north and south, can have their vertical course observed. It fortunately happens that every one of these north and south lines can be traced to the foot of the cliffs, and are there seen to meet other lines which traverse the entire thickness of the deposit. The direction of these lines is from vertical to 8° or 10° E.; it necessarily happens, therefore, that such lines, if prolonged, must approximate or cross, which accounts for the various distances observed upon the beach between the north and south lines. Hence it is evident that the new red sandstone is structurally composed of octohedral masses, having their major axes much extended through the thickness of the deposit. At the point where fig. 7. was taken, there is a subsidence of a few inches to the west.

Guided by analogy, geologists have concluded that the jointed structure of sedimentary rocks has been superinduced by the agency of heat, and if the divisional lines of the new red sandstone have been so produced, the same agent would account for the other phænomena. The depression of the new red sandstone so as to admit of the accumulation above it of the whole of the cretaceous and tertiary series, placed it under conditions of temperature quite adequate for the purpose; for, from the decomposition of the water which the rocks would naturally contain, the oxygen would enter into combination with the iron, so abundant in the deposit, and form a peroxide, except where, the same causes producing a decomposition of the surface of the limestone fragments, a carbonate of iron would result; the *quantity* of the carbonic acid overcoming the stronger affinity of the iron for the oxygen.

At the southern extremity of Great Haldon, near Ugbrook, also in the valley of the Teign, the neighbourhood of Torbay, and everywhere along its western outline, the new red series rests on the edges of the older carbonaceous or graywacke rocks. About Newton, between Berry and Torquay, and between Newton and Totness (Bowbridge), conglomerates and sandstones of this age fill deep valleys, as if the slate rocks had presented great inequalities of surface before the newer formation was superimposed.

Their association with the porphyry of Exeter, &c., will be noticed under the head of the Igneous Rocks (*posteà*, p. 470).

The absence of organic remains in this deposit is very general, nor has any exception yet been noticed in the great mass which occurs in South Devon, though it presents every variety of mineralogical character. An abundance of peroxide of iron has been stated to be unfavourable to their preservation, but in many places, as near Exminster, the deposit presents thick beds of yellow sands, which are equally deficient in animal reliquiæ. The fossil castings of worms, already noticed, to be seen near Sidmouth, Exeter, and other places, are the only indications that animals of any sort existed; but to this we may add, that the upper surfaces of the slabs of sandstone in the cliffs west of Sidmouth present straight irregularly branched bodies, and sometimes of considerable size, composed of fine-grained, compact sandstone. They can be easily removed from the slab in which they lie; and if of vegetable origin, no structure is preserved, as in the fossil wood of the greensand.

Carbonaceous Deposits. (Map, Pl. XLI. Sect. Pl. XLII. Figs. 2, 3, 6, and 8.)

In a communication to the Geological Section of the British Association, at the Meeting in August 1836*, Prof. Sedgwick and Mr. Murchison first separated from the older rocks of the West of England certain deposits which constitute an extensive portion of North Devon, presenting a very peculiar mineralogical character, and to which, from the abundance of terrestrial vegetation contained in a particular portion, they gave the name of culm deposits. In a paper I read to the Geological Society in March 1836†, I noticed certain conglomerate and sandstone strata, exhibited in Ugbrooke Park, near Chudleigh, and other adjacent places, and which I erroneously supposed to be included in the transition series. In the autumn of the same year, I pointed out these deposits to Prof. Sedgwick, who considered them as a portion of the culmiferous beds of the centre of the county.

The first point of interest connected with the carbonaceous series in South Devon is the position of certain deposits in the neighbourhood of Newton Bushel, and of those in Ugbrooke Park above alluded to. Rydon Hill (Pl. XLII. fig. 2.), near Newton, consists, in its upper portion, of black shales and conglomerates, containing much disseminated carbonaceous matter and occasional vegetable remains; so that in general aspect and character the deposit differs widely from the slate series of the district. It has a very limited range, and has been accumulated on an uneven and abraded surface of older rocks. Figs. 9. and 10. (see next page) represent this unconformable position as exhibited in quarries near Newton. On the right of the road

* See Report of the British Association for 1836, Notices of the Sectional Meetings, p. 95.

† See Proceedings, vol. ii. p. 414.

to Totness the carbonaceous beds occur on the east side of the great mass of Conator limestone; and on the opposite side they abut against a vertical wall of limestone, acquiring considerable thickness, and in the lower portion present the same alternations of carbonaceous shales with siliceous bands as the culm series of North Devon. The pebbles of the conglomerate beds are mostly siliceous, and may have

Fig. 9.

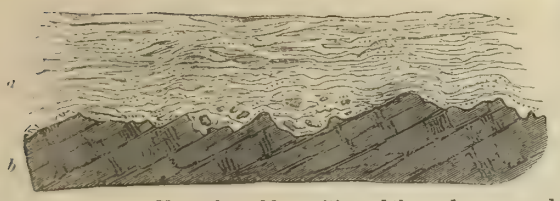


Fig. 10.

Unconformable position of the carbonaceous deposits (*a*) to the older rocks (*b*) near Newton.

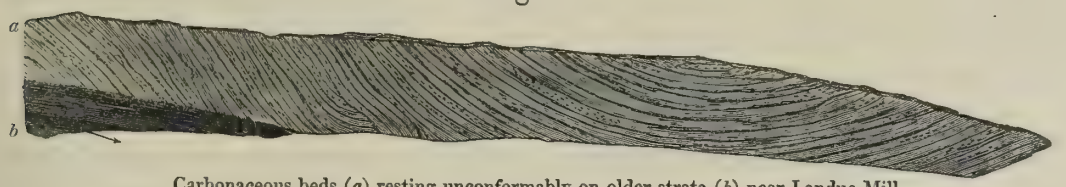
been derived from the quartz veins of the older slates; but in the section represented by Fig. 9. the lowest beds are seen to contain blocks of limestone derived from the subjacent rock, and mostly angular or but slightly water-worn. The unconformable position of this mass can also be observed along the road from East Ogwell to Newton, and in the valley near Bradley House.

The rocks of Ugbrooke Park closely resemble those of Rydon Hill, consisting of the same black earthy shales, coarse sandstones, and siliceous conglomerates; but their superficial extent is much greater. They moreover contain pebbles of green porphyry, and of a black flinty rock like Lydian stone; but in the numerous beds of this conglomerate which I have examined, I have never detected a fragment of granite. Their position, like that of the Rydon deposit, is unconformable, as may be seen south of the Lewell stream, near the Chudleigh Rock, and in the sections represented in Pl. XLII. fig. 6, fig. 8, E. Vegetable remains may be found in the sandstone quarry, by the road leading from Chudleigh to Whapple-well, and in Ugbrooke Park generally; impressions of large Calamites occur also in the Orchard-well valley, but not sufficiently well preserved for the determination of the species. We may safely conclude, that these deposits are of the age of some portion of the true coal-measures of the other parts of England.

The culm series of Professor Sedgwick and Mr. Murchison undoubtedly passes round the eastern side of Dartmoor, and is in contact with the granite as far south as Skeriton, a little west of Dean Prior (see map, Pl. XLI.). Along its external edge it first rises, about Exeter, from beneath new red sandstone; near Chudleigh its relations to the calcareous masses of the base of Great Haldon are rather obscure, and such is also very generally the case in its course westward. There can

be no question as to the geological position and equivalents of the arenaceous and conglomerate beds of Rydon and Ugbrooke, as over the whole of central Devon, and throughout the narrow band south of Dartmoor, the argillo-carbonaceous character of the culm series is remarkably uniform, but the mineralogical resemblance is not so great as to warrant their being considered portions of one formation. The central trough of Devon is believed by Prof. Sedgwick and Mr. Murchison * to be of the same age as the South Wales coal-field, on the evidence of mineral character. The inquiries of Mr. Lonsdale established the place which the South Devon limestones should hold in the scale of British formations; by means of these alone can be determined the age of the carbonaceous system. If along the line from Dean Prior to the Haldons the culm measures pass beneath the slates and limestones to the south, they must have a much greater antiquity than has been assigned to them; but if, like the beds of Ugbrooke and Rydon, they are superior to them, they may, as suggested by Professor Sedgwick, be the equivalents of the coal-measures. In the north of Devon, along a line extending from Fremington to Hockley Bridge, north of Bampton, the carbonaceous rocks pass downwards into the older system, which composes the range of Exmoor. At Boscastle, on the opposite side of the trough, the coast-section exhibits a similar passage. From this point inland, the line of separation is best marked by the distinct vegetation and barren tracts of the carbonaceous grit beds; but no good section is to be found of the relative positions of the two deposits till we reach Landue Mill, near which a road-cutting in 1837 exposed the following section, where the carbonaceous beds,

Fig. 11.



Carbonaceous beds (*a*) resting unconformably on older strata (*b*) near Landue Mill.

of inconsiderable thickness, rest unconformably upon slate and shales, very rich in fossils: from this point again the junction-line presents no section, though it can be easily traced upon the surface, until it abuts against the granite of Dartmoor, north-east of Tavistock.

Crossing the granitic tract of Dartmoor, and in the direction of the line of bearing of the carbonaceous rocks from the coast, we meet them again about Holne, perfectly identical in character and appearance with the beds about Tavistock; but on this side also there is the same difficulty as to sections. On the road from Buckfastleigh, south of Ashburton, to Holne, and in the ascent to Hembury Castle, the

* See vol. iv. p. 669 *et seq.*

fine fissile slates which compose the base of the hill appear in one place to arch over, and the carbonaceous beds set on, at the summit. They occupy a similar position from Skeriton to Holne Bridge, where the deep valley of the Dart cuts through both deposits nearly at right angles, and we might expect a good natural section; but the strata here are much disturbed by trap, which breaks out along the bed of the stream. At the point of junction both rocks are nearly vertical, or if there be any inclination, it is in favour of the infraposition of the carbonaceous beds: on the north bank, however, and at a very short distance, as near the entrance to the woods, they are to be seen dipping gently north, and for a considerable space. In the ascent from Ashburton to Buckland the fine-grained fissile slates dip south for some distance, till at length they arch over, as in the Hembury section, and the carbonaceous rocks set on with a south dip at the crown of the hill. The section at Rew Mill affords little information, but it should be visited by any one investigating the structure of the country. At Place, near Ashburton, the carbonaceous rocks, for the first time, come in contact with the great band of lower limestone, and on the north side of the great quarry they seem to rest on its surface. From this point they again retreat, and form the high barren tracts known as Ashburton, Ramshorn, and Goodstone Downs. At New Inn, the two rocks are not seen in juxtaposition, but at two points not very distant the carbonaceous beds are either horizontal, or have a gentle northern dip, and the fine slate rock has a steep southern pitch.

On the opposite side of the Bovey valley an interesting section was exposed, at the time the new house opposite the Chudleigh Rock was built: the excavations were altogether in perfectly horizontal carbonaceous shales and sandstones. A well was sunk at the same place (Pl. XLII. fig. 6.), and it was then seen, that these beds were only about fifteen feet in thickness, resting on the edges of highly inclined claret-coloured slates, dipping in the same direction as the Chudleigh lime-rock, and such slates as from Chudleigh to Barton may be seen at several places to underlie the limestone. In this section we are reminded of that at Landue Mill (p. 459, fig. 11.), and also of the Rydon sections (p. 458, figs. 9, 10.). The breadth of slate, which in position is inferior to the Ashburton limestone, and is interposed between it and the boundary-line of the carbonaceous rocks, is very unequal; yet if the latter dip beneath the rocks of South Devon, we must be prepared to admit, that whilst at one place they are in contact with that limestone, yet, at only a short distance, they dip beneath a great thickness of slate, which is undoubtedly inferior to that limestone; besides which, the outline of the carbonaceous rocks does not conform to the strike of the slates and limestones.

The evidence from sections leans towards the priority of the South Devon deposits, but it must be admitted that the structure of the country is obscure, from great disturbance; the present elevated position of the carbonaceous beds along the

flanks of Dartmoor does not belong to the question, as it is due to the long subsequent protrusion of the granite.

On the other hand, the limestone of the Ashburton band is exceedingly carbonaceous, containing even seams of anthracite. The sections about Chudleigh are undoubtedly obscure, but I have endeavoured to represent the structure of the country from Oxencombe, beneath Great Haldon, to the disappearance of the limestone near Chudleigh Bridge, by figures 8 A. to E, Pl. XLII. Taking as a guide the apparent dip of the carbonaceous rocks at one place, they would seem to pass beneath the limestone; but against this is the well-section already noticed, and the fact, that where the base of the limestone is exposed, as at Waddon Barton (fig. 8 B.), it is seen to have a very different rock subjacent to it, namely, a fine-grained claret-coloured slate, like that which underlies the equivalent calcareous masses of Newton and Barton. The equivocal appearances along the south base of the Haldons (fig. 8 A.) are caused by a downcast fault of unequal amount, which has brought the different members of two distinct series of rocks into juxtaposition; and the small patches of limestone about Orchard-well, Luton, Colmansford, and Larcombe Bridge, are not included masses, but merely portions of a great unconformable band protruding here and there, owing to the inconsiderable thickness of the shales which cover it.

The mineral contents of the carbonaceous rocks of South Devon are numerous. Tin and copper have been found beneath Ashburton Down, where the Owlecombe mine has been long worked; tin also occurs at Ilsington, near which is an old stream-work, and at Christow, seven miles north of Bovey. Lead is found in the above-named parishes, and that of Hennock, between Bovey and Christow, contains silver. Some beds rich in iron have been worked at Ilsington, and they also contain numerous small garnets; in the same rock, but in an altered state, contiguous to the granite, are fine crystals of pseudomorphous amethystine, purple and red quartz. The limestone near Oakhampton contains copper in nodules, which are compactly imbedded in the rock, and present a radiating structure like the pyrites of the chalk, but without their metalliferous appearance; in the kiln the copper becomes a bright green carbonate.

Referable perhaps to this period, or more properly to the conglomerates of Rydon and Ugbrooke, is that thick mass of limestone breccia which at Petit Tor (Pl. XLII. fig. 1.), east of Babbacombe, is interposed between the solid limestone and the new red sandstone. It has been produced at the expense of the subjacent limestone, which is much diminished in thickness, and has partaken of a disturbance which has affected both it and the underlying slate. It was moreover consolidated and again fissured before the formation of the new red conglomerate, from which therefore it must be separated.

The evidence of the age of the carbonaceous rocks deducible from organic remains is as yet very meagre. *Pecopteris lonchitica*, *Neuropteris heterophylla*, *Sphenopteris latifolia* or *acutifolia*, with a *Cyclopteris*, are the only plants I have seen from the shales, except the Calamites of Ugbrooke and Orchard-well, which I cannot refer with confidence to any species described by Ad. Brongniart or Prof. Lindley. This

Flora, so far as it goes, is that of the carboniferous period. In the black limestones occur *Goniatites miscolobus* and *G. crenistria*, mountain limestone species.

Strata subjacent to the Carbonaceous Deposits.

(Map, Pl. XLI., Sect. Pl. XLII. figs. 1. to 4, 6. to 8.)

The general arrangement and direction of the older rocks of South Devon can be easily ascertained by means of long lines of roofing-slate, chains of lenticular masses of limestone, and subordinate beds of trappean matter; and by the same means the Devonshire deposits can be connected with those of Cornwall. It was on such considerations as these that I proposed the divisions suggested in 1839*, and which, though purely artificial, may still be conveniently adopted; they are as follows; but it is hoped that the map, Pl. XLI., and sections, Pl. XLII., will render the prolixity of a mineralogical description unnecessary.

1. Coral limestone of Newton, Barton, Torquay.

2. A red deposit, chiefly arenaceous, with a slaty structure, and occasional interchanges of fine fissile beds, extending from Paignton, Windmill Hill, near Berry Pomeroy, and across the Dart about Sharpham. It constitutes also the middle district of South Devon, where it is locally arenaceous, as at Blackdown and Morleigh, and it forms the east side of Plymouth Bay, south of the limestone of Mount Batten.

3. There is a considerable development of limestone north of the above, and which appears to dip beneath it: such is the position of all the limestone masses about Yalberton, Berry, and the lower limestone of the Ogwell country.

4. Separated from the above by a band of slate, with occasional lines of fine-grained fissile beds fit for roofing-slate, is a lower limestone mass and contemporaneous trappean beds, which ranges from Staple Hill, by Bickington, Ashburton, Buckfastleigh, and Dean Prior. At South Brent these beds are cut off by the granite of Dartmoor, but they resume their course on the opposite side about Newnham. They cross the river at Saltash, and are continued through South Cornwall, by Tredinick, Polpever, Looe, Fowey, Gorran, St. Michael, and Veryan to south of Falmouth, containing subordinate limestones and calcareous slates, with fossils throughout.

5. A lowest division may contain all the slate-range north of the foregoing.

Divisions 1, 3, 4, and 5, have a southern dip. The central portion of South Devon, which includes the red arenaceous series, presents many undulations. Proceeding south the dip of the beds is permanently reversed, and from Kingsbridge to the Prawle it is to the north, so that these strata must be considered as the equivalents of that part of the section on the north which rises from beneath the Plymouth limestone. In both localities are lines of roofing-slate, but limestone bands are wanting in the southern section; this however is in accordance with a general fact, that the calcareous masses have a southern dip throughout South Devon and Cornwall.

The rocks of the series above described are well calculated to correct the notions of those who would rely on mineralogical character and structure. The age of the beds between Stoke Fleming and the Prawle, as compared with the rest of the older strata of South Devon, is sufficiently clear; yet instead of a descending series

* Geol. Proceedings, vol. iii. p. 123.

of clay-slates, of an uniform character and composition, we see them pass from clay-slate, through talcose and micaceous slate, to true gneiss—the progressive metamorphic forms of strata, which are the geological equivalents of the lower part of the old red sandstone.

§ 1. *The coral limestones of Newton Bushell, Ogwell, Kingskerswell, Barton, and Torquay.*—These deposits form so striking a feature in the scenery of this portion of the county, and the map, Pl. XLI., so sufficiently indicates their positions, that a detailed account of their range and extent is not required.

The thin calcareous deposits constitute the uppermost portion of the older rocks of South Devon, and in most places they are distinctly stratified ; they also present two systems of divisional joints, one set of which runs a few degrees W. of N., and a cross set S. of E. ; locally, however, considerable deviations will be observed, some of which are given in the following table :—

Localities.	Range of joints.		Strike of the beds.	Dip of the beds.	
Chercombe Bridge	N. 45° W.	N. 25° E.	N. 25° E.	40° E.S.E.	In three places.
Do. Second Quarry.....	N. 45° W.	N. 45° E.	id.	id.	The same on the other side of the stream.
Ogwell Park.....	id.	id.	id.		
	N. 70° W.	id.	id.		
	N. 45° W.				
	N. 25° W.	N. 65° E.			
	N. 45° W.	N. 45° E.			
Orchard-well	N. 25° W.	N.	N.		
	N. 45° W.				
Wolfsgrove	N.	E.	N. 25° E.	60° E.S.E.	
	N.	N. 70° W.	N. 45° E.	S.E.	
Ipplepen.....	N. 45° W.	N. 45° E.			

Another curious point connected with the structure of many of the great limestone masses of South Devon, particularly those of Brixham, will be noticed under the head of cleavage.

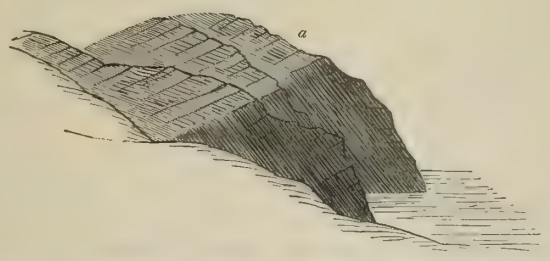
The relations of these large calcareous masses to the subjacent slate rocks is not very evident. At Pulser, the shales, at their junction with the base of the Torbrian limestone, through a thickness of about two feet, contain small lenticular portions of limestone, arranged in parallel lines, which correspond with the bedding. About Ogwell (fig. 3.) the limestone sets on, in compact beds, after a few trifling alternations with shales, and such is very generally the case.

Although these limestones dip in the same direction with the slate rocks of the district, and often at considerable angles, they do not appear to descend with them to any great depths, but either to thin away, as at Staverton (as does also the lower Ashburton band at Staple Hill), or else to end abruptly downwards, as near Newton (road-section) fig. 7. Pl. XLII. and the limestone of Denbury, as if they had been formed on a previously deposited mass of sediment, now converted into shales and slates. At Bunker's Hill, near Totness, the limestone, which on the south side of the hill dips with the slates composing the central portion, wraps round,

and on the north side is inclined to the north, or conforms to the slopes of the hill. There is no ambiguity here respecting the stratification of the limestone, as it is made very apparent by alternating seams of good anthracite, though cleavage planes dipping south also traverse both limestones and slates; the Dartington limestone, at its west extremity, pitches down on the edges of the subjacent slate. The limestone of Yalberton, though it has all the appearance of being included in the grauwacke series, is found, when traced towards the Dart, not to dip with the slates and sandstones exposed in that section, but to have thinned away on the surface close to the village of Stoke Gabriel. In the same manner the great calcareous mass of the south and west of Torbay terminates in inconsiderable beds of shaly limestone, along an E. and W. line from Galmpton Creek towards Brixham, by Churston Ferrers, and of which there is a good section at Galmpton.

The termination of the great calcareous group of S.E. Devon, where it is exposed in the coast-section at Sharkham Point, is represented in the accompanying woodcut.

Fig. 12.



Termination of the limestone group (*a*) of South Devon, at Sharkham Point.

Along their N. and W. edges these limestones set on, either as a capping to the slate, when they often present a wall or low escarpment to the north, or they rest against the south slopes of the ridges and low hills of slate, as at Bradley; they then dip with the slope, but carry the edge of each constituent bed of limestone to the level of the crest of the ridge of slate. This is perhaps the most remarkable feature of these masses, and may be seen about Denbury and East Ogwell: whatever the angle of dip may be, or however far the succession of beds may be carried on, in a given linear direction, the upper surface forms a table-land. It is also the case with the lower limestone of Ashburton and that of Plymouth. An observer has only to ascend one of the higher slate hills in the vicinity of any of these limestone masses to be assured of the fact here mentioned, and which serves to connect all our limestone masses by one common feature.

Any inquiry whence so large a quantity of calcareous matter was originally derived, though a question of much geological interest, would be irrelevant in a mere local description; but it may be observed, that both in North and South Devon the existence of limestone appears in very many instances to have depended on subaqueous volcanic disturbance, as it is interstratified with beds of compact and ashy trap: thus the rock quarried at Leny near Launceston is a vesicular hornblendic mass, largely

impregnated with calcareous matter; and beds of contemporaneous trappean ash run parallel with the limestones from Launceston to Oakhampton. In South Devon the coral limestones are in many places superincumbent on great sheets of volcanic materials, with which in some instances, as at North Whilborough, they alternate; and the compact greenstones of South Devon contain a variable, but in all cases, a considerable proportion of lime. This association may be accounted for by supposing, either that subsequently to such eruptions the waters may have held a greater quantity of lime in solution; or that the bed of the sea was altered and placed under conditions more favourable for the production of limestone masses.

Very little personal examination of the principal limestone mass of South Devon will satisfy any one, that it has resulted from the labours of *Polypi*; in other words, existed as a coral reef at the close of the transition period. In the parish of East Ogwell each bed is entirely composed of branching corals in the positions in which they grew; and in the parish of Denbury the partings between the beds of limestone are of volcanic sand, which is easily removed, and we then obtain an upper surface studded with projecting stars and branches, as perfect as when the sand was thrown upon them and suspended the labours of the Polyps. Among existing zoophytes the lamellated and cellulated orders seem to be the principal agents in constructing reefs, and their analogues mainly compose the Devonshire limestone.

The calcareous rocks of South Devon, in their structure, as well as in the position, preservation, and grouping of their corals, afford abundant evidence that their production was analogous to that of modern coral reefs; and in their general position they agree with the reefs of the southern hemisphere, where the Polyps raise their habitations on the summits or slopes of submarine hills to a level with the surface of the water, and hence the table form of land which the limestone masses still preserve.

A local association of certain generic, and even specific forms is often to be observed; thus the limestone of Newton abounds in *Cyathophyllæ* and *Coscinoporæ*; that near Chercombe Bridge seems to have been almost exclusively constructed by *Favosites polymorpha* and *F. spongites*: whilst about Denbury, *Favosites alveolaris* and other allied species are most abundant.

The organic remains contained in the rocks of South Devon are very numerous, and in beautiful preservation. A critical examination of a collection of these fossils by Mr. Lonsdale led to very interesting results connected with the older rocks of this country, and the rectification of an error as to their age and place. The generally adopted opinion at that time was, that the slates and limestones of South Devon were of the same age with the slates of the Berwyns and the limestone of Bala. Mr. Lonsdale's correction was arrived at by the only safe guide,—zoological evidence, by which he established, from the intermediate character of the forms, between those of the true mountain limestone on one hand, and those described by Mr. Murchison in the Silurian System on the other, that the older South Devon limestones were the equivalents of those deposits which in other parts of England underlie the mountain limestone.

The old red sandstone is in general mineralogically different, and sparingly fossiliferous; and until the publication of Mr. Murchison's work, we were but little acquainted with any forms from these thick deposits. This work contains descriptions and figures of seventeen fishes, twenty-seven shells, and one crustacean, in all forty-five species. It is proper only to state, that of these not one has as yet been found in South Devon, whilst, on the other hand, they strikingly resemble such as are contained in the arenaceous deposits in North Devon, which underlie the carbonaceous beds, and so far agree in position with the old red sandstone of the opposite coast of Pembrokeshire.

In no other part of England do we appear to have an association of fossil forms identical with those of South Devon. In 1839 I noticed the occurrence of certain similar forms in the rocks of the South of Ireland; and, guided by the identification of about forty species, I suggested, that in the Rhine and Eifel countries (Paffrath, Bensberg, Gladbach, Gerolstein, &c.) there were equivalent deposits*.

The not adopting, in this memoir, the name "Devonian" for these deposits, is not owing to ignorance of its value as a geological group, but because such a name is at variance with the nomenclature of well-

* Vide Report of British Association, 1839, p. 69.

established groups, and because the beds form only one portion of a great primary fossiliferous series for which we already possess materials for subdivisions founded on zoological views, which are preferable to geographical ones.

Though the limestone band of Chudleigh has not had that attention bestowed upon its fossils which it deserves, we know enough to place it with certainty with the slate and calcareous system of South Devon, rather than with the black limestone of Lew Trenchard, Trescott, Drewsteignton, &c. The *Favosites? fibrosa*, which alone forms strata many feet thick, connect it with the limestones of Ashburton and Plymouth, where that coral is equally abundant: it contains *Stromatopora concentrica*, in common with all the subordinate bands of Broadhempston, Staverton, &c.; *Stromatopora polymorpha* and large *Strygocephali*, as do the Ogwell beds; and the *Loxonema præterita* and *Buccinum spinosum*, so numerous at Newton Bushell.

The suite of fossil shells and zoophytes contained in the limestones of Newton, Barton, and Babbacombe correspond in so remarkable a manner, that they may safely be considered as one group, formed at the same time, and under like conditions; but the Newton quarry, generally speaking, exhibits the specific characters of the fossils much more distinctly than that of any other locality, and it is therefore the best place to which the collector can be referred. This quarry has afforded me the following list of species, which is two-thirds more numerous than the list above alluded to*, by the addition of the zoophytes identified and described by Mr. Lonsdale†, and of the new species of Professor Phillips‡ and Mr. J. de Carle Sowerby§.

Brontes flabellifer, *Goldf. Nova Acta*‖.
Calymene Latreillii, *Stein. Mém. Soc. Géol.*¶
——— Sternbergii, *Munster, Beiträge.***
Orthoceras cinctum, *Sow. Min. Con.*
——— ellipsoideum, *Phil. Pal. Foss.*
——— pyriforme, *Sow. Silur. Syst.*††
——— tubicinella, *Sow. Geol. Trans.*§
——— ventricosum, *Stein. Mém. Soc. Géol.*
Cyrtoceras armatum, *Phil. Pal. Foss.*
——— fimbriatum, *Phil. id.*
——— marginale, *Phil. id.*
——— nautiloideum, *Phil. id.*
——— nodosum, *Phil. id.*
——— obliquatum, *Phil. id.*
——— ornatum, *Gold. MS.*
——— quindecimale, *Phil. Pal. Foss.*
——— reticulatum, *Phil. id.*
Cyrtoceras rusticum, *Phil. Pal. Foss.*
——— tridecimale, *Phil. id.*
Nautilus germanus, *Phil. id.*
Goniatites excavatus, *Phil. id.*
——— globosus, *Munster, Abhandl.*‡‡
——— serpentinus, *Phil. Pal. Foss. & Geol. Yorks.*§§
——— transitorius, *Phil. id.*
Bellerophon hiulcus, *Sow. Min. Con.*
——— striatus, *Bronn. Leth. Geog.*‖‖
——— Wenlockensis, *Sow. Silur. Syst.*
——— Woodwardii, *Sow. Min. Con. Index.*
Buccinum acutum, *Sow. Min. Con.*
——— arculatum, *Schloth. Petref.*¶¶
——— imbricatum, *Sow. Min. Con.*
——— spinosum, *Sow. id.*
Murex? harpula, *Sow. id.*

* Vide Report of British Association, 1839, p. 69.
‡ Phillips, 'Palæozoic Fossils.'
‖ Nova Acta Acad. Cæs. Leop. Cur. Nat. t. xix.
** Beiträge zur Petrefactenkunde, Heft 1. 1839, Heft 3. 1840.
‡‡ Abhandl. über Planuliten und Goniatiten, 1832.
‖‖ Lethæa Geognostica.
† Geol. Trans., 2nd Series, vol. v.
§ Geol. Trans. vol. v.
¶ Mém. Soc. Géol. de France, tome i.
†† Mr. Murchison's Silurian System.
§§ Geol. Yorkshire, Part 2.
¶¶ Schlotheim, Petrefactenkunde.

Pleurotomaria antitorquata, *Munster, Beiträge.*
——— aspera, *Sow. Geol. Trans.*
——— cancellata, *Phil. Pal. Foss.*
——— impendens, *Sow. Geol. Trans.*
——— monilifera, *Phil. Pal. Foss.*
Schizostoma tricincta, *Munster, Beiträge.*
Macrocheilus elongatus, *Phil. Pal. Foss.* (Phasianella?)
Terebra Hennahii, *Sow. Geol. Trans.*
——— nexilis, *Sow. id.*
Turritella abbreviata, *Sow. Min. Con.*
Loxonema reticulata, *Phil. Pal. Foss.*
——— lincta, *Phil. id.*
Turbo textatus, *Munster, Beiträge.*
Euomphalus annulatus, *Phil. Pal. Foss.*
——— circularis, *Phil. id.*
——— radiatus, *Gold. MS.*
——— serpens, *Phil. Pal. Foss.*
Nerita spirata, *Sow. Min. Con.*
Pileopsis vetusta, *Sow. Min. Con. & Geol. Trans.*
Cardium alæforme, *Sow. Min. Con.*
——— minax (Pleurorhynchus), *Phil. Geol. York. & Pal. Foss.*
Modiola scalaris, *Phil. Pal. Foss.*
Mytilus Damnoniensis, *Phil. id.*
Megalodon carinatum, *Gold. Pet. Germ.*
——— cucullatum, *Sow. Min. Con.*
Pterinea.
Avicula texturata, *Phil. Pal. Foss.*
———? reticulata, *Phil. id.*
Pecten plicatus, *Sow. Min. Con.*
Leptæna fragaria? *Sow. Geol. Trans.*
——— nodulosa, *Phil. Pal. Foss.*
——— rugosa, *Dalm., His. Leth. Suec.**
Orthis arachnoidea? *Phil. Geol. York. & Pal. Foss.*
——— arcuata, *Phil. Pal. Foss.*
——— crenistria, *Phil. Geol. York. & Pal. Foss.*
——— granulosa, *Phil. Pal. Foss.*
——— Hardrensis, *Phil. id.*
——— interstrialis, *Phil. id.*
——— resupinata, *Phil. id.*
——— lens, *Phil. id.*
Delthyris cuspidata, (Spirifer, *Sow. Min. Con.*).
——— distans (Spirifer, *Sow. id.*).
——— hirundo? (Spirifer, *Phil. Pal. Foss.*).
——— microgemma (Spirifer, *Phil. Pal. Foss.*).
Delthyris nuda (Spirifer, *Sow. Geol. Trans.*).
——— heteroclita, (Calceola, *Defrance.*).
——— oblata (Spirifer, *Sow. Min. Con.*).
——— plebeia (Atrypa, *Sow. Geol. Trans.*).
——— phalæna, *vid.* concent., *V. Buch, Mém. Soc. Géol. France.*
——— simplex (Spirifer, *Phil. Pal. Foss.*).
——— subconica (Spirifer, *Sow. Min. Con.*).
——— speciosa, *Bronn. Leth. Geog.*
——— unguicula (Atrypa, *Sow. Geol. Trans.*).
Strygocephalus? Burtini, *Defrance, Dict. Sc. Nat.*
Terebratula acuminata, *Sow. Min. Con.*
——— anisodonta, *Phil. Pal. Foss.*
——— aspera, *Schloth. Petref.*
——— bifera, *Phil. Pal. Foss.*
——— cassidea, *Dalm., His. Leth. Suec.*
——— comta, *Phil. Pal. Foss.*
——— crenulata (Atrypa, *Sow. Geol. Trans.*).
——— cuboides (Atrypa, *Sow. id.*).
——— desquamata (Atrypa, *Sow. id.*).
——— ferita, *V. Buch, Mém. Soc. Géol. France.*
——— flexistria, *Phil.*
——— galeata (Atrypa), *Dalm.*
——— hastata, *Sow. Min. Con.*
——— juvenis, *Sow. Geol. Trans.*
——— Mantiæ, *Sow. Min. Con.*
——— prisca, *Schloth. Petref.*
——— proboscidialis, *Phil. Pal. Foss.*
——— pleurodon, *Phil. Geol. York. & Pal. Foss.*
——— pugnus, *Sow. Min. Con.*
——— reniformis, *Sow. id.*
——— rhomboidea, *Phil. Geol. York. & Pal. Foss.*
——— sacculus, *Sow. Min. Con.*
——— Wilsoni, *Sow. id.*
Cyathocrinites geometricus, *Gold. Pet. Germ.*
——— ? nodulosus, *Phil. Pal. Foss.*
——— geometricus, *Gold. Pet. Germ.*
Actinocrinites triacondactylus, *Mill. Hist. Crin.*†
Platycrinites interscapularis, *Phil. Pal. Foss.*
——— pentangularis, *Mill. Hist. Crin.*
——— tuberculatus, *Mill. id.*
Sphæronites? *His. Leth. Suec.*
——— tessellatus, *Phil. Pal. Foss.*

* Lethæa Suecica.

† Miller, Natural History of Crinoidea.

Stromatopora concentrica, *Gold. Petref. Germ.*
——— polymorpha, *Gold. id.*
Fenestella, *Lons.* (Retepora, *Gold.*) *Silur. Syst.*
——— abnormis, *Lons. id.*
——— antiqua, *Lons. id.*
Retepora infundibulum, *Lons. id.*
——— prisca, *Gold. Petref. Germ.*
Lithodendron, *Gold. id.*
——— cæspitosum, *Gold. id.*
Amplexus, *Sow. Min. Con.*
——— tortuosus, *Phil. Pal. Foss.*
Cyathophyllum turbinatum, *Gold. Petref. Germ.*
Cystiphyllum (Cyathophyllum, *Gold.*), *Lons. Silur. Syst.*
——— Damnoniense, *Lons. Geol. Trans.*
——— vesiculosum.

Strombodes, *Schweigger Beobachtungen, &c.*
——— vermicularis, *Lons. Geol. Trans.*
Astræa, *Linn.*
——— ananas, *Gold. Petref. Germ.*
——— helianthoides, *De Blain.*
——— Hennahii, *Lons.*
——— pentagona, *Lons.*
Porites, *Lamarck.*
——— pyriformis, *Lons. Silur. Syst.*
Coscinopora, *Gold.*
——— placenta, *Gold. Petref. Germ.*
Favosites, *Lamarck.*
——— fibrosa (Calamopora), *Gold. Pet. Germ.*
——— Gothlandica, *Lam. Anim. sans Vert.*
——— polymorpha, } (Calamopora)
——— spongites, } *Gold. Pet. Germ.*

§ 2. *Red arenaceous slaty strata.*—The slate range, subjacent to the coral limestone, requires only a short notice, as any description would be purely mineralogical, and details of those local variations common to all deposits, have now little interest or value attached to them. These slates and shales are remarkably deficient in organic remains over wide areas, but productive localities occur in the parishes of East and West Ogwell, Denbury, Berry Pomeroy, the neighbourhood of Torquay, and in Mudstone Bay. They suggest the notion of slow and tranquil deposition, and an uniform condition as to depth; while the casts of molluscous and other animals, whose most delicate markings are admirably preserved, indicate that the sedimentary matter was in an exceedingly minute state. It is only with the red arenaceous portion, which often resembles the old red sandstone of Herefordshire, that different conditions are required,—such as would produce alternations of conglomerates, sandstones and shales. Near Broad Sands is an included calcareous bed, composed of rounded blocks of limestone imbedded in a hard matrix; the blocks show that at this early epoch, lime rocks had been formed in some quarter; but, in the absence of organic remains, it is impossible to say, whether they were conveyed from a distance, or were derived from some reefs existing in the vicinity.

Although the slates and coral limestones both belong to the same geological period, and were probably in many instances contemporaneous deposits, the suite of organic remains of the slate system differs widely from that of the coral limestones, a change, the natural result of the different habits of marine animals. Thus the *Terebratulæ*, which so swarmed about the reefs where they had the means of fixing themselves, that we find twenty-three species in the Newton quarry alone, are altogether wanting in the slate. The constancy of certain forms to rocks which indicate similar conditions is very remarkable; thus we find the same *Fenestellæ*, *Turbinoliæ*, *Pleurodyctium problematicum*, &c., ranging through the whole middle slate district of South Devon and continued into Cornwall; but it would be impossible in a local memoir to enlarge on the subject of the connexion constantly to be observed between the mineral character of rocks and the forms of the inclosed organic remains. The large *Strygocephali* of South Devon evidently covered extensive surfaces, as oyster-beds do now, thick strata being entirely

composed of their uninjured shells at Chudleigh, Chercombe Bridge, Bradley, and Plymouth ; again, the habits of the *Calceolæ* are made very evident by the position in which they are found, being invariably in the thin partings of shale which separate the lower beds of sedimentary limestone. These calcareous flagstones probably soon became solid compact strata, to which fucoids attached themselves, and among which the *Calceolæ* lived.

The researches of fossil zoologists have hitherto been principally engaged with the forms which the calcareous groups of South Devon have afforded; the slate system not having as yet received much illustration; whenever this shall be done it will be found that the prevalence of certain generic forms, and even a total change in species, are unsafe guides as to relative age ; that though the shells which lived about the coral reefs of South Devon, resemble to a considerable extent such as occur in the mountain limestone tracts of other parts of England, yet that the slates of South Devon afford fossils which suggest comparisons with those from districts described by Mr. Murchison: such and very many other conditions must be taken into account before organic remains can be made the framework of an order of superposition for the older rocks.

The few following species, together with many not yet made known or described, will be readily found in the slates about Ogwell :—

Fucoids.
Turbinolopsis celtica, *Lamx. Expos. Méthod.**
Cyathophylla.
Fenestella antiqua, *Lons. Silur. Syst.*
Pleurodyctium problematicum, *Gold. Pet. Germ.*
Cyathocrinites nodulosus, *Phil. Pal. Foss.*
Crinoidal stems.
Spirifer speciosus, *var.* alatus, *V. Buch, Mém. Soc. Géol. France.*
——— aperturatus (Terebrat.), *Schloth. Petref.*
Strygocephalus ——? (undescribed species).
Orthis compressa, *Sow. Silur. Syst.*
——— arachnoidea, *Phil. Geol. York.& Pal. Foss.*
Orthis sordida (Leptæna), *Sow. Geol. Trans.*
Leptæna depressa, *Dalm., His. Lethæa Suecica.*
Modiola scalaris, *Phil. Pal. Foss.*
Trochus Bouei, *Stein.* n. s.
Orthocerata.
Calymene accipitrina, *Munster, Beiträge.*
——— granulata, *Munster, id.*
——— lævis, *Munster, id.*
——— Sternbergii, *Munster, id.*
Asaphus granuliferus, *Phil. Geol. York. & Pal. Foss.*
Olenus punctatus, *Stein. Mém. Soc. Géol. France.*

§ 3. *Limestone of Yalberton, &c.*—The small subordinate masses of limestone indicated on the map are usually thin-bedded, but they occur in very distinct layers, are hard, sonorous, and very dark-coloured. They are also valuable, as they yield large slabs, and burn into a good lime, of which much is employed in agriculture throughout South Devon: organic remains but seldom occur ; I have seen only *Stromatopora concentrica* or *polymorpha.*

§ 4. *Lower Limestone of Ashburton.*—This great calcareous band of limestone closely resembles the foregoing in character and appearance ; it has also much carbonaceous matter in seams, in which respect it is very like the limestone of Bunker's Hill, near Totness ; and in both cases the vegetable matter seems due to marine rather than to terrestrial vegetation, as the only impressions I have found are those of fucoids. Fossil shells (Brachiopoda) and corals (Cyathophylla) are abundant, but the close compact structure of the rock renders it impossible to obtain detached

* Exposition Méthodique; for the other works referred to, see the titles in the notes to p. 466.

specimens ; the *Favosites** ? *ramosa*, however, appears as plentifully as at Plymouth and Chudleigh.

II. Igneous Rocks. (Map, Pl. XLI. Sect. Pl. XLII. figs. 1. to 4, and 6.)

Earliest Epoch.

§ 1. *Interstratified.*—The earliest proofs which we perceive in South Devon of igneous agency are the numerous bands of hornblendic matter and ashes interstratified with the older slate rocks.

In the coast-section at Babbacombe, trap rests on beds of shale ; and near the level of the sea (fig. 1.), the trap presents a rounded undulating surface, to the outline of which other beds of shale conform ; but the enclosing strata, neither above nor beneath, afford any indications of intrusion, or alteration by heat. Limestone shale, succeeded by compact limestone, followed the deposition of the trap ; the whole series dipping in one direction, and the disturbances which affect this part of the country being clearly of more recent date than the trap. Mr. De la Beche, it must be admitted, considers the trap at this place to be intrusive, and to be the cause of the dislocations ; but in the numerous instances which South Devon presents of undoubted eruptive masses, the mode of association is very different. All we have here is a gradual change from one rock into another, which cannot be better given than in the words of Mr. De la Beche's description : " The trap becomes so altered in its character as it ascends, that the highest portions scarcely deserve the name, presenting, where not in contact with the limestone, a base that effervesces, contains green specks and iron pyrites†."

To the west of Babbacombe the beds of trap again rise, and are followed by a much more considerable thickness of compact greenstone, which arching over forms the hill known as Black Head ; and the sea-cliff affords a section of the igneous rock with the underlying shales, &c. At Islam Farm this mass of trap, much reduced in thickness, is interposed between slates below and limestone above ; a similar position is to be observed at Chapel Hill, near Tor Moham, where in several places the trap can be traced passing from a bright green hornblendic rock into a harsh limestone with seams of ashes. From its very unequal thickness, this, and other similar masses, were probably erupted very near the spots at which we now find them.

In the neighbourhood of the little hamlet of North Whilborough, $3\frac{1}{2}$ miles west of Babbacombe, igneous and aqueous rocks are similarly associated ; the trap putting on various forms and acquiring considerable thickness. In some places it is a compact

* *Caunopora* of Phillips, Pal. Foss. Cornwall, &c., 1841.

† Geol. Trans., 2nd Series, vol. iii. p. 168.

greenstone, in others a coarse hornblendic slate, and in both states it alternates with shaly limestone at the base of the great limestone mass of the above-named place.

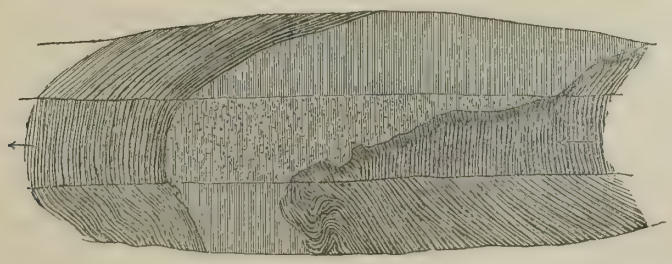
Another very instructive instance is to be found in the parish of East Ogwell. The lowest part of the trappean mass is there compact and crystalline, and rests everywhere on slate; to this follow friable arenaceous beds, occasionally alternating with more solid ones, until they gradually give way to shaly limestone, which is quickly succeeded by the coral reef-limestone, so thickly developed in this and the adjoining parishes. These hornblendic beds swarm with organic remains, chiefly Fenestellæ, columnar joints of Crinoidea, and shells of Brachiopoda.

The contemporaneous trap rocks cannot be separated from the intrusive ones by inspection of mere hand specimens, particularly should they have been taken from the harder beds, for a crystalline arrangement is often as perfect in the one as in the other; even their included position, among sedimentary rocks, would be accounted for by some geologists (and equally erroneously) as instances analogous to phænomena which have been described from the coal strata of the North of England. But in addition to the evidence from included animal remains, which is not always available, the contemporaneous trappean beds, from having been exposed to precisely the same conditions with the associated deposits, present the same divisional lines both of jointed structure and slaty cleavage, as may be seen in the village of East Ogwell. (Pl. XLII. fig. 3.)

Similar contemporaneous trappean beds, the results of subaqueous volcanic action, occur at various intervals throughout the South Devon series: and such eruptions, occasionally accompanied with sheets of molten matter, and the subsequent dispersion by the action of the waves, as in the recent instance of Hotham Island, suggest that they originated by similar events at that distant period; submarine banks may thus have been formed where before was deep water, and thus the bed may have become suitable for animal life, and fit spots on which Polyps could fix and raise their structures.

§ 2. *Intrusive.*—The intrusive trappean rocks which the slate region of South

Fig. 13.



Ground-plan of a dyke intersecting slates near West Down, between Ogwell and Ashburton.

Devon presents are exceedingly numerous, and their eruption has produced very

decided effects on the physical features of the country. They usually occur either at intervals along the ridges of hills, or at the points of conical elevations, in the form of protruding masses; and their injected nature is established by such natural sections as that presented at the break in the line of hill through which the Lemon stream flows past Holbeam Wood (Pl. XLII. fig. 2, Hobbin Wood, Ord. Map, two miles west of Newton Bushell), by the alteration which they have produced in the rocks which include them; or again by such horizontal sections as the one given in the woodcut, fig. 13, which represents the ground-plan of a dyke to be seen near West Down. In this instance it is very evident that the intrusion of the trap was subsequent to the time when the slates took their present structure. The whole line of the lower limestone band of Bickington affords numerous instances of intrusion of trappean rocks amidst slates and limestones; in the town of Ashburton, and in the street leading out to Buckland, is a large quarry in which broken beds are visible completely included in the greenstone.

Wherever the trap produced a conical slate hill (a very common feature), radiating fractures necessarily resulted; and wherever these have been of sufficient width to allow the trappean matter to ascend to the surface, we have there a central mass with radiating branches, proving the fluid state of the injected rock: instances may be seen between Woodland and Bickington; road-cuttings, and other excavations, also expose the terminations of small veins which do not quite reach the surface.

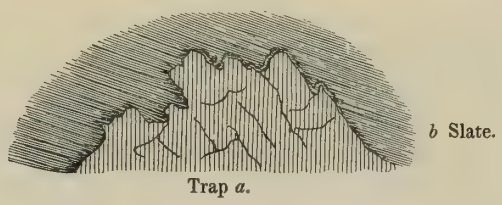
The amount of alteration which the heated trap has effected, varies considerably. At Holbeam the dykes have quite obliterated the lines of deposition, and converted the slates into a compact flinty mass; at Bishopsteignton, where we may suppose the beds were originally in a slight degree calcareous, as they still retain traces of organic remains, the shales were reduced nearly to fluidity, and changed into a red jasper. Flexible asbestus often occurs at the junction of intrusive hornblende rocks with the slates, as at Highwick. In very many points also the eruptive trap rocks of South Devon resemble the Ophites of the South of France in the general outline of the country, producing lines of conical hills; they have been erupted in a fluid or semi-fluid state; they have possessed sufficient heat to have produced important changes on the rocks in contact with them; but they seldom have flowed over the neighbouring surface. Near Totness, in the quarry by the side of the Newton road (Pl. XLII. fig. 4.), is an exception; the trap is there seen resting on a dislocated surface of slate and limestone, and at one place the laminæ are much contorted, as if by the weight and lateral pressure of the trap: another instance occurs at Wear.

There are two mineral products which have resulted from these hornblendic rocks. Magnesia is abundant in those layers of limestone which immediately succeed the subordinate trappean beds; and from the large proportion of that earth in all hornblende rocks, we can easily account for its association with limestones which were deposited immediately after the eruptions that disseminated so much trappean matter in a state of subdivision at these particular places. Again, where great trap dykes have intruded among limestones, and long subsequent to their formation, as at Bickington, Ashburton, Bishopsteignton, Kitley, &c., the calcareous beds invariably contain magnesia. Manganese is also very abundant in South Devon, and great quantities are annually raised. In the majority of instances the metal is found in immediate association with masses of erupted trap, and filling the cracks and fissures which resulted from its intrusion, as at Denbury, Ideford, &c. The hornblendic are the only igneous rocks which con-

tain manganese, and it is found in them from whatever part of the world they are brought. This circumstance would seem to indicate that the manganese has been given off by the trap; but the quantity of that earth contained in trap rocks has never been ascertained to exceed 0·25, whilst we constantly find bunches of metal of great extent and richness associated with dykes of inconsiderable bulk.

Fig. 14, which was taken from a road-section near Pulser, represents a mode of occurrence distinct from the cases already described; the mass of trap (*a*) is evidently intrusive, on account of the broken edges of the slate surrounding it, but it was, previously to its protrusion, compact and jointed. There is much trap in

Fig. 14.



Section near Pulser, junction of trap and slate.

the higher parts of the same ridge, which was evidently in a fluid state when it reached the surface. All masses in that condition at great depths, may have portions nearest to the solid crust in various stages of temperature, and some sufficiently cooled to be solid rock; so that whenever any disturbance should force the liquid mass amidst sedimentary deposits at the surface, portions of the mass which had already become solidified below, might also be brought up along with, or forced laterally among, such deposits. In this case, a greater amount of disturbance might be expected than when the entire body of trap was fluid; but at Petit Tor is an analogous case, where large angular blocks of limestone have been forced laterally into the slate, and have merely crushed the edges of the beds immediately about them.

Carbonaceous Epoch.

§ 1. *Interstratified.*—Volcanic products are interstratified with the beds of this series, in the same manner as in the older slates, presenting analogous mineralogical characters and modes of association. The phænomena indeed are identical, and prove, that in some quarters, volcanic agents continued in operation after that change (whatever it was), of which the character of the organic contents of the two deposits is the permanent evidence; being purely marine in the one, and partly terrestrial in the other. The broad and frequent bands which are associated with the lowest carbonaceous beds along their southern boundary, and which are more considerable than any trappean masses interstratified with the older slate rocks, seem to indicate that the change was accompanied by even increased vol-

canic activity. The contemporaneous trap of the carbonaceous period is however more local in its character, as it seems not only to be entirely wanting throughout the central portion of the deposit, but also along the northern boundary, among beds which in age we must consider to be the equivalents of the southern ones. These subordinate trappean beds may therefore be briefly described as ranging parallel with the southern outline of the carbonaceous series, and as partaking along the north side of Dartmoor of all the flexures and dislocations which the intrusion of the granite has produced. Good natural sections are exhibited along the course of the Teign, where that river cuts the beds at right angles to the strike; at Crocombe, near Chudleigh, fifteen trappean beds, varying from a few inches to several feet in thickness, alternate with black shales, and sections exhibiting similar phænomena may be obtained in many other places.

§ 2. *Intrusive.*—Though trap rocks have been erupted among beds of the carbonaceous series, the area occupied by the latter does not present, when compared with an equal portion of the older slate system, the same number of instances of intrusive masses. Beneath Ramshorn Down, $2\frac{1}{4}$ miles N.W. of Newton, are protrusions of greenstone, and the shales and flagstone are much altered; at Penwood, a little further east, the whole of a conical hill has been converted into flinty jasper; and at Hennock, $1\frac{1}{4}$ mile N.W. of Chudleigh, as well as Botter, great masses of erupted trap are in contact with, but do not enter the granite.

The igneous products hitherto mentioned seem to have been exclusively hornblendic, but the close of the carbonaceous period was marked by eruptions of a peculiar character, which produced the crystalline rocks of the neighbourhood of Exeter. This trap has been so often noticed, that no details respecting its mineralogical character are here requisite; it is simply a porphyry, generally red, only occasionally green, the base varying in texture from earthy to compact, and containing large crystals of that variety of felspar which has been made a distinct species, under the name of *Ryakolite*: near Silverton and some other places it contains a large proportion of mica, and some hand-specimens can hardly be distinguished from dark granite. This rock is seen at the eastern extremity of Great Haldon, at Dunchideock Bridge, &c., resting on the carbonaceous shales. It forms a considerable portion of Pocombe Hill, in which are several quarries; and on the western slope of the hill, the road exposes a good section showing the position of the porphyry resting on the smooth surface of the black shales; dipping as well as at the same angle with them: beneath the castle of Exeter, it rests on shales, from which place it plunges under the new red sandstone in the direction of Heavitree.

It has long been a favourite notion, that the lowest conglomerate beds of the new red series originated in a disturbed condition of things, and that in some instances, as in the case of the porphyritic rocks of Exeter, the true cause of the disturbance was apparent; it will be as well therefore to notice this rock

with reference to such views. At all the above localities the porphyry rests on the undisturbed surface of the carbonaceous shales. A quarry yielding a very compact variety of the rock is worked on the summit of a hill at Western, in the parish of Ide: in this instance (one of those I believe adduced in proof of the association of the porphyry with the new red sand formation) the igneous rock would appear to rest upon the carbonaceous deposit, of which the lower part of the hill on every side is composed. The entire thickness of the porphyry has been cut through, and here, as elsewhere, it rests on carbonaceous shale; a section exhibited in a lane leading down to the stream near Dunchideock Bridge, might seem an exception to the above, and place a thick mass of porphyry within the new red sandstone; but I believe it to be the result of a small fault running parallel with the stream, and which has let down a portion of the porphyry to the west. As yet, I have seen no unexceptionable example of the Exeter porphyry resting on beds of new red conglomerate, but instances are abundant where the conglomerate rests on the abraded surface of the porphyry; and it must be remembered that the blocks of porphyry which enter so largely into the composition of the lower conglomerates, prove that the porphyry had cooled down into a crystalline mass before the production of the conglomerate commenced.

It will be seen, therefore, that this rock rests upon carbonaceous shales, and hitherto has not been observed to cut through them. It is found only in detached masses, placed at very different elevations, owing to the subsequent disturbances which have affected the district; and it has contributed largely to the sedimentary beds next in sequence to those on which it rests; and these reasons induce us to consider the few remaining portions of the rock as evidences of an extensive submarine eruption of felspathic lava which took place at the close of the carboniferous period, and long before the production of the lowest beds of the Exeter conglomerate.

The most recent trappean rock, so far as age can be established by association with beds of ascertained relative antiquity, is that of Wear. The experienced geologist is here quickly stimulated to look for those causes which produced the masses of crystalline limestone, jasper, and blocks of fused and altered rocks scattered over the surface of the soil, and built into all the walls, particularly in the vicinity of Bishopsteignton. A portion of the erupted trappean matter which has caused these appearances has been cut through longitudinally by the road from Teignmouth to Kingsteignton. In this section, the mass nearest Lower Wear is compact, and traversed by veins of quartz; about one hundred yards further on, is an included bed of hard and splintery slate, about fifteen feet thick; to the north of the road are several quarries, and in one of these the trap rests on the edges of limestone. Above Higher Wear included angular blocks of trap first appear, which in a short distance become so numerous as almost to form a conglomerate cemented by a trappean base; in a quarry at the east end of the section the trap assumes a columnar structure, and is very compact. By the map, Pl. XLI., the trap is seen to be the axis of a ridge, which has a direction from north-east to south-west; with slates and limestone resting against it on each side. The dyke can be traced by Colway Cross up to Rowdown Cross, a little beyond which it enters the new red sandstone: in the contrary direction it is just covered by a low rounded hill of shale, from beneath which it reappears at the level of the Teign at Clay-cellars: and on the opposite bank, owing to a fault in the direction of the valley, it forms

a cliff of some elevation. The intrusive nature of the dyke is proved by the great changes it has produced along its course: the slates have lost their colour, and are either porous or baked and splintery; the limestone shales have been fused into jasper; the solid limestone has been crystallized to a very considerable distance from the dyke; the new red sandstone has been hardened into a compact mass, and the lines of stratification are in many places quite obliterated; but there are innumerable vertical fissures, which are coated with manganese. This altered rock is quarried above Bishopsteignton, as well as on the opposite side of the dyke, above Lindridge; and its course in the new red sandstone can be carried on by several abandoned excavations.

Certain appearances, such as that of the conglomerate above noticed, seem to require for their solution the supposition, that this was a subaqueous eruption; whilst the porous vesicular nature of some of the trap would indicate that the pressure of water was slight. With respect to the angular blocks contained in the compact greenstone, we must suppose that the liquid mass brought up with it from below, in the same manner as modern lavas, portions which had become solidified.

If the highly inclined position of the beds at Staple Hill, of which the upper portion is certainly post-cretaceous, has resulted from the local elevation of the slate on which they rest, and this elevation is owing to the great mass of trap which the hill contains, we ascertain the age of another band of erupted trap; and there are appearances exposed in a road-section on the opposite side of the same hill, on the way up to Ingsdon, which confirm this inference.

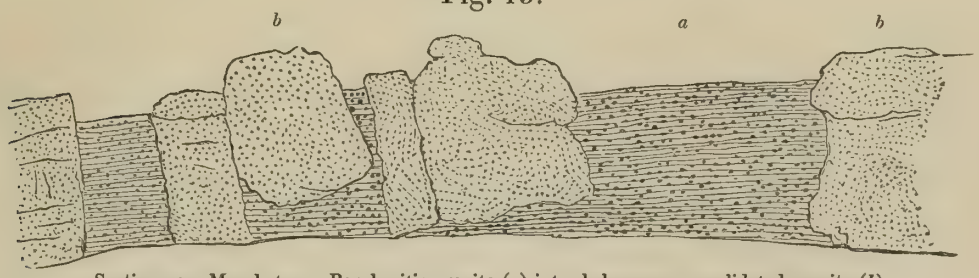
The granite of Dartmoor presents a similar composition and texture over the greater part of its area. The principal portion is porphyritic, containing large crystals of felspar, but its constituents vary locally in their relative proportions. At one place, near Oakhampton, is a very beautiful white felspathic rock, resembling pure trachyte: another form is that in which schorl takes the place of mica, as is the case along the edges of the moor, but I know of no spot where the mica is developed in such large plates as it usually is in most other extensive granitic masses. Wherever bare surfaces of this granite are exposed, as along the upper courses of the Teign and Dart, linear veins will be observed, filled with compact schorl. They are never very wide, and have the same direction (about east and west), which is that of one set of joints, but I have never seen a cross set so filled. There is another set of veins, usually much wider than the preceding, filled with matted crystals of quartz and schorl, which evidently occupy cracks opened in the rock after it had become hard and compact; and the growth of the contents of the fissure has been by successive additions from the walls on each side, until the two portions met, in the middle. Geodes also occur in the granite, lined with schorl, and crystals of quartz. Similar cavities have afforded large and beautiful specimens of tourmaline. These minerals give a very distinct character to a portion of the Dartmoor granite, which occurs universally along the edges of the mass and at various places within the interior, often forming tors, surrounded by a rock of a very different composition and appearance.

The granite of Dartmoor is altogether an intrusive mass; and it was stated by Prof. Sedgwick and

Mr. Murchison, at the meeting of the British Association at Bristol in 1836*, that it must have been erupted subsequently to the completion of the carbonaceous deposits, as along the northern slope of Dartmoor, about Oakhampton, beds of that part of the North Devon series had been greatly altered and disturbed by it. The same phænomena occur on the south. At Higher Alway, near Bovey, a branching vein of granite of considerable thickness extends a quarter of a mile from the main mass; and another vein may be seen at Lower Alway. At Ilsington, south-west of Bovey, a small mass protrudes through the carbonaceous shales, and the whole line of contact, along the southern flank of the moor, is an altered rock. In the upper part of the valley of the Dart, in the Holne Chase, numerous instances of granitic veins may be observed in the sides of the roads which have been cut through the woods, and the range of several smaller ones may be traced across the road at Ash, above Spitchwick.

The observation of Prof. Sedgwick and Mr. Murchison above quoted, as to the age of the Dartmoor granite, applies necessarily to that schorly portion alone which comes in contact with sedimentary deposits, for the entire mass is not of the same age. Fig. 15. represents a section exposed near Murcheton

Fig. 15.



Section near Murcheton. Porphyritic granite (*a*) intruded among consolidated granite (*b*).

and shows the manner in which the usual porphyritic granite has intruded itself among such as had already become compact and jointed, and containing schorl; and other instances occur in the same neighbourhood. Again, this porphyritic and micaceous granite is traversed by elvans of a compact, fine-grained stone, presenting no distinct crystallization of any of its constituents, and they have evidently been protruded posterior to the consolidation of the rocks in which they occur: good examples may be seen in the neighbourhood of Lustleigh, about six miles to the westward of Chudleigh. The Dartmoor region, like every other composed of plutonic rocks erupted on a great scale, presents fewer facilities for geological observations than inhabited and more intersected districts, but the facts, here noticed, warrant the conclusion that it contains granite of three distinct ages.

In Lower Normandy, on the opposite coast of France, where the geological features present so many points of resemblance with those of the west of England, the granite is an intrusive rock, and is generally supposed to be of no great antiquity; it is also intersected by trap dykes; in Devonshire, on the contrary, every dyke is cut off by the granite.

Dartmoor, as a physical region, presents two very distinct features: 1st, the great dome-shaped masses, of which Cawsand is the best illustration; and 2ndly, the long vertical walls, with lines of ruin and confusion, constituting the wild scenery about Lustleigh, and along the road from Bovey to Moreton. Viewed in connection with the Cornish masses of erupted granite, Dartmoor is the eastern

* See Athenæum 1836, p. 612, explanation of Section.

extremity of an axis of crystalline rocks, which, gradually decreasing in elevation and superficial importance, extends westward as far as the Scilly Islands. The general direction of the axis is about south-west to north-east, and we should naturally expect to find, in the undulations of the surface of these erupted masses, a general parallelism in conformity with this direction; such, however, is not the case, the whole surface showing north and south lines of hills, valleys and water-courses; a circumstance which suggests that the present outline and configuration of Dartmoor are the result of disturbing causes which have acted subsequently to its projection.

The Dartmoor mass of granite may be estimated as occupying about 200 square miles of surface: at Cawsand it attains an elevation of 2000 feet, but near Bovey it is exposed in the vicinity of secondary, and even much more recent formations little above the level of the sea; yet over the whole of this area, there is not the slightest appearance that any stratified formations were deposited; its deep valleys would certainly have presented some few traces of them, even allowing for extraordinary denudation, had the present outline of surface existed prior to only the cretaceous series.

In the study of detritic formations, the identification of mineral fragments becomes of almost equal importance with that of organic remains; in the present instance they afford only negative testimony; but as, from the absence of volcanic fragments in the conglomerate eocene beds of central France, we infer the relative age of the volcanic outbursts of that region, so, as no granitic pebbles have been found among the various materials of which the new red conglomerate is composed, we may conclude, that at the period of its accumulation the granite of Dartmoor could not have been exposed, particularly when we bear in mind that the two formations are at present separated only by the valley of the Teign.

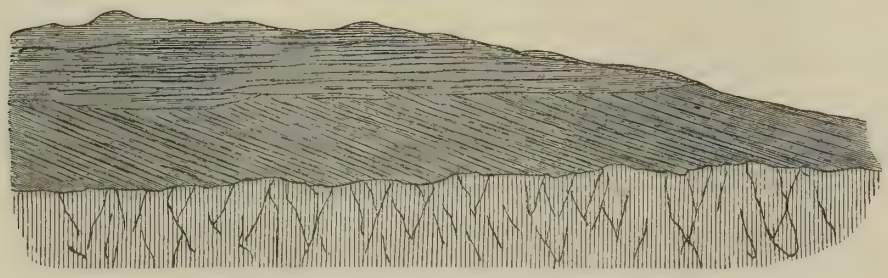
The beds of the greensand of the Haldons and the Bovey valley, in the thin mica, sharp quartzose crystals and seams of felspar clay, suggest that they may have resulted from a decomposed granitic district; but here again, although fragments of all the older rocks occur in the conglomerate beds at the base of the greensand, granitic pebbles are altogether wanting; nor do we meet with them until we arrive, in ascending order, at those superficial accumulations (p. 447) which cap the Haldons, when they appear in great abundance, associated with rolled flints, and worn like marine shingle. Possibly, then, the rise of the granite of Dartmoor in its present form may belong to a period comparatively recent, nor would such an inference be at variance with much that is already known: the granite of Arran, according to Professor Sedgwick and Mr. Murchison*, is more

* Geol. Trans., 2nd Series, vol. ii. pl. 3. p. 353, 1828; vol. iii. part 1. p. 34, 1829.

recent than the new red sandstone, and that of Brora, than the oolites. On the Continent, the observations of Elie de Beaumont*, Hugi†, Studer‡, and Dufrénoy§, show that in the Oisans, Bernese Alps, and Pyrenees, the central axes of granite must have been in a fluid state since the cretaceous period. In no part of the world can any granitic mass be proved to be of great antiquity,—an ancient fundamental rock; the masses which are now in contact with any of the palæozoic strata are all intrusive; and the granitic eruptions of the S.W. of England may be perhaps added to the proofs, already numerous, that this particular crystalline form was most extensively projected at the close of the secondary period, and caused or accompanied that contrasting condition of surface which the subsequent tertiary period must have presented.

Important changes have resulted in Devonshire from the intrusion of so many heated masses among sedimentary rocks, and some of these have been already noticed. The greenstone trap of Holbeam, Denbury, &c., very constantly obliterates the lines of deposition or cleavage of the slates. Fig. 16. represents a case to be seen in a quarry near Ogwell, where a great mass of trap would appear to have imparted diagonal lines to the slate. With the assistance of map, Pl. XLII., all the

Fig. 16.



Slate with oblique structure resting on trap near Ogwell.

various intrusive masses of trap will be so easily found by the field geologist, and the effects they have produced are so obvious at each locality, that any description in addition to what has already been incidentally given in other places, is not required.

Nor are less important changes exhibited in the neighbourhood of the granite: carbonaceous shales are converted into black slate; arenaceous beds become mica-

* Faits pour servir à l'Histoire des Montagnes de l'Oisans, Mém. Soc. Hist. Nat. de Paris, tome v. Mémoire pour servir Désc. Géol. de France, tom. ii.; also Dausse sur la forme, &c., de la chaine des Rousses, Mém. Soc. Géol. de France, tome ii. p. 125, 1837.

† Alpen Reise.

‡ Bulletin Soc. Géol. de France, tome ii. p. 51 *et seq.*, 1831; also Carte Géologique des Chaines entre les lacs de Thun et de Lucerne, Mém. Soc. Géol. de France, tome iii. p. 379, 1839.

§ Mém. pour servir Désc. Géolog. de la France, tome ii.

ceous sandstones, earthy hornblendic beds are rendered highly crystalline, as near Ilsington, and the associated strata abound with garnets; the development also of mica in beds which previously did not contain any (none occurring at a short distance) is very common. Some of the projected granite veins, which are usually composed of a homogeneous rock, hardly crystalline, terminate towards their points in a curious assemblage of plates of mica.

The old slates have been much altered along the line of the trap dyke near Bickington, N.E. of Ashburton, as may be seen where it crosses the summit of the high hill between that place and Ingsdon; the slate is also much changed, often passing into jasper. Large blocks of a similar altered rock are to be seen between Bickington and the bridge along the old road; also about Higher Wear on the Teign. These blocks, derived from beds of old slate affected by heat, are in one instance collected in great numbers, and of large size, along the summit of a ridge of carbonaceous sandstone and conglomerate, particularly at Hestow Farm, near Lindridge.

Cleavage and Jointed Structure.

Incidental mention has been made of those great divisional joints which traverse whole formations in given directions, and which are more particularly observable in the slate, limestone, and new red sandstone strata; besides these, the whole of the older series of South Devon rocks present what have been termed lines of cleavage.

Our knowledge of this branch of geological inquiry is exceedingly imperfect; it seems however to be generally supposed that the phænomena are due to the agency of heat, and an instance has been mentioned (p. 479) in which an intruded mass of heated trap may, on a small scale, have superinduced such a structure; and in further confirmation of this view, it will be found, that wherever the general appearance of the rocks in any particular spot indicates a greater degree of alteration than elsewhere, that there the subordinate lines of roofing-slate show an increased number of cleavage planes; and when we note the very great variation which the rocks of the same age may present in this respect, from one place to another at no great distance, we see enough to feel satisfied that such a structure can be no criterion of relative geological age.

The superinduced cleavage structure of South Devon is as follows. In the south-east portions of the county the lines are in the same direction with the planes of deposition, and occasionally coincident, as at the Ingsdon Down and other quarries (Pl. XLI.); but very often, when at first sight such appears to be the case, a more careful examination shows that one set of lines crosses the other at small angles; and it is this structure which so frequently renders it difficult to procure perfect specimens of the fossils contained in those slates: thus the cleavage and bedding of the fossiliferous slates of Ogwell would be supposed to conform; but the cleavage planes are constant, whilst the bedding is waved,

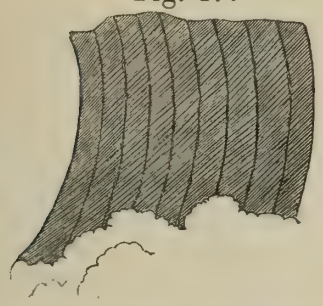
so that the agreement is only occasional. Throughout South Devon the planes which have a southern dip, and consequently a direction about east and west, are always the smoothest and best; on the Newton and Totness road, at Little Hempston, Staverton, north-west of Totness, &c., two planes or more may be observed, whilst in the slates N.E. of Plymouth there are as many as four systems of planes, all distinct from that of deposition.

This structure is not confined to the slate rocks, the cleavage planes passing equally through the subordinate bands of the contemporaneous hornblendic beds, as at East Ogwell (Pl. XLII. fig. 3)and Datton Mill; and affecting also masses of limestone of vast thickness, as about Gatcombe, two miles N.E. of Totness, and Bunker's Hill, where it is often difficult to ascertain the bedding in consequence of the more strongly marked lines of cleavage.

Many facts illustrative of the jointed and cleavage structures may be collected in that part of Torbay where the slate rocks come down to the coast between the limestone and new red sandstone.

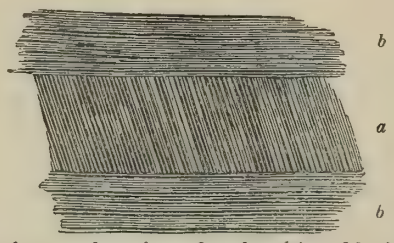
The great limestone masses about Brixham have similar cleavage planes, cutting through their entire thickness with striking regularity (fig. 17.); the bedding here being also very distinct. This structure is not confined to the old rocks of South Devon, nor is it any proof of their priority, as they do not alone afford roofing-slates. Throughout the carbonaceous series, slate-quarries are very numerous, but in no instance that I know of, are they worked parallel with the bedding. In a large quarry near Lew Trenchard, roofing-slates alternate with coarse flagstones (fig. 18.); the latter subdividing parallel with the

Fig. 17.



Cleavage in limestone near Brixham.

Fig. 18.



Oblique cleavage planes in roofing-slate (*a*), and horizontal in coarse flagstone (*b*) near Lew Trenchard.

planes of deposition, but the intermediate slates cleaving at a high angle. The contortions of this series of deposits are so constant and extraordinary, that illustrations of every possible position of the

Fig. 19.

Cleavage planes in arched strata near Yealm Bridge.

plane of cleavage, with relation to strike and dip, may be found often in a single quarry. The woodcut (fig. 19.) represents a section across the large slate-quarry near Yealm Bridge, at the back of Werrington Park, worked in arched beds of the carbonaceous series, and where the cleavage planes obviously conform to the lines of deposition at one place, and at another, within a very short distance, cut them at right angles. The older series of deposits which rise from beneath the carbonaceous beds on the north, if followed along the coast-section, exhibits the very striking fact of cleavage planes, with one constant angle and direction, cutting through strata of various mineralogical characters and most curi-

ously contorted. The greatest amount of disturbance is to be seen in Morte Bay, where the bedding also is apparent, as well as the order of deposition of each stratum by means of lines of organic remains. Fig. 20. exhibits the manner in which these planes pass through some arched strata near Ilfracombe.

Most generally, the strike of the cleavage agrees with that of the beds, as in the older series just alluded to; but it will be found, that as soon as the carbonaceous deposits set on, as at Fremington, this strike alters and makes a small angle with that of the bedding: so also with the fossiliferous strata of South Devon; where, though the two lines of strike often coincide, they will yet be also found at various

Fig. 20.

Section of cleavage planes passing through bent strata near Ilfracombe.

angles to one another, and instead of dipping with the beds, to have an opposite inclination; in fact, the superinduced structure is everywhere much more strongly pronounced than the original one of deposition; and it pervades districts over which all order of accumulation is wanting, or more probably was never marked at all; so that the greatest caution is constantly required. There can be no question, that throughout large districts the cleavage lines have been given as those of stratification; such indeed was the case, only a very short time ago, with the whole of the Exmoor group: and calculations were made from these observations, which gave a thickness to some of the deposits entirely at variance with the conditions under which those strata were formed.

The few foregoing observations tend to show, that this remarkable change in the arrangement of the particles has not extended, in this part of England, to any beds higher than those of the carbonaceous series; and that it was superinduced subsequently to the disturbances which produced the contortions in all the older strata of Devon; and again, with reference to a given geological epoch, we know, from the materials in the lower conglomerate beds, that the process, as just stated, had been completed before the commencement of the new red sandstone formation; but there are also fragments in the Ugbrook strata which were derived from rocks possessed of a slaty structure; and the limestone blocks in the lowest beds of carbonaceous deposits at Rydon show that the limestone generally at that early time had its present crystalline, jointed structure.

Faults, Fractures and Dislocations of the Strata.

These phænomena are so familiar, that they require neither representation nor

description beyond the statement whether any district under consideration presents such appearances, and if so, their degree of prevalence and general directions.

The whole of the county of Devon may be described as an assemblage of fragments of deposits, probably once continuous : it does not, that I am aware, present many of those vast dislocations which geologists have observed in other parts of the world, or even in this country, but the general amount of disturbance is extraordinary,—every quarry, every range of cliff, every artificial cutting for a road, or excavation for a dwelling-house, offering instances in endless succession. The vicinity of Dawlish may serve as an example (Pl. XLII. fig. 5.); but as to describe in detail the faults of such a district would be an endless task, the following observations relate more particularly to the connexion of faults, where such is possible, with the phænomena of those disturbing operations which successively placed the various rocks in the conditions and situations in which we now find them.

The surface of the new red sandstone district is remarkable for its undulations and deep combes. Many of these, it will be found, as exposed in the deep cuttings on each side of Dawlish, are not the result of mere excavation, but of elevation or depression; the angular inequalities, which must, in the first instance, have been produced, having been subsequently modified, as well as the hollows filled in part with the coarser debris, whereby an undulating outline resulted; and the upper surface never indicated the disturbance which can be traced beneath. (Pl. XLII. fig. 5.) At Watcombe, however, there is a fault which has evidently been produced since the rounding process was completed over the rest of the neighbouring district. The scenery at this place may be briefly described as the result of the subsidence of a tract half a mile in length, and less than a quarter in breadth, to much below its former level; leaving an open space bounded by vertical cliffs, one of which is of great height. The direction of the fault, from the coast inland, is due east and west, the amount of dislocation regularly diminishing; but soundings prove that it is continued with a like course beneath the sea. Should this spot ever be submerged, the angular summits of the cliffs would be soon removed; the larger materials would be collected below, in the same way as we now find them in the Dawlish valley, and on its next exposure as dry land, it would be in appearance a true valley of denudation, corresponding in every particular with those of the Sid, Otter, &c. The phænomena at Watcombe are just such as have recently been produced at Seton, except that, at the former, the amount of dislocation has been greater. The cause assigned for the Seton subsidence does not seem to be supported by concurrent evidence, even should it be deemed adequate; and, with respect to Watcombe, it is altogether inapplicable; whilst the east and west direction common to both, and other considerations, seem to point to some deeper-seated cause.

It may also be suggested, whether the arched strata at Petit Tor (Pl. XLII. fig. 1.), and the east and west vertical cliffs, may not have been produced by the same disturbance which caused the Watcombe fault. At the junction of the shales and limestone at Petit Tor, and at the level of the beach, good instances may be seen of the great pressure the beds experienced when the disturbance took place.

If the speculation as to the conditions under which the Bovey carbonaceous beds were formed be correct, and we couple with this belief the fact of several marine and estuary deposits having been raised, we must admit that, within a comparatively recent period, the surface of this part of England was placed at nearly its existing level, then at one much lower, and that it has again been raised to its present

position. That the amount of oscillation has been unequal on different parts of the coast is most probable; but the greatest vertical movement did not much exceed seventy feet, and we may perhaps infer that such tracts as the ancient forest beneath Torbay, now permanently submerged, are portions which have not regained their former levels.

The whole of the west of England has experienced similar unequal movements, the amount of elevation increasing from east to west. Thus, the raised beds of the Dart (Staverton) are much above the level of those of the Exe; and still further west, as in Cornwall, they attain a much greater altitude; and indeed along the whole western side of Great Britain, the recent marine beds have their highest range.

The periods of these three distinct relative positions of the land with respect to the sea-level (which we must assume to have been constant) may be very distant from any historical times, but the forms of animal life were such as apparently have occupied this country only a few centuries back; and though the marine species contained in the raised marine beds seem to be few, which is but a negative fact, yet they afford no indication of a higher temperature than the present, and possibly the inference which I ventured to deduce in the account of these deposits may be ultimately established.

Intimately connected with this particular period, and intermediate between two distant faunas, are the marked effects of water moving in a definite direction, carrying along with it the loose surface materials, and filling the open fissures and cavities with debris. The traces of this action occur only at inconsiderable heights.

Antecedent to this, was a period when the country had a configuration exactly similar to the existing one, but was inhabited by races of animals which indicate a more elevated temperature than the present. Of the vegetation of this period, which we must suppose to have been different from that of the submerged forest of Torbay, not the slightest vestige has yet been found, though the requirements of the large Pachyderms would imply that it must have been abundant.

We know that during the period of those large Mammalia the fissures in the limestone rocks were open chasms: had they existed in that state whilst the denuding process was in action, and which laid bare the very beds traversed by the fissures, the latter must have certainly been filled with red sandstone debris; but, from the animal remains contained in the breccias, we learn that the chasms are of later origin, and were filled after the whole country had been in the condition of dry land for a long period. If we take the fissures of the Chudleigh country as a guide, we find that in every instance they have been opened along the lines of joints in the lime rocks: thus, the great mass of debris cemented by calcareous matter, which crosses the quarry at Chudleigh rock, like a huge wall of coarse masonry, is the

contents of a north and south joint, from which the solid rock has been removed on each side: the same quarries afford many analogous instances. All the joints in a mass of arched limestone near Barton have been similarly opened and filled; and these, as well as all the fissures which are to be found along the base and west slopes of the Haldons, as at Orchard-well, Lindridge Hill Wood, &c., suggest that the strata must have been subjected to great tension, which caused them to yield along the joints as lines of least cohesion.

The whole period of denudation was probably one of slow emergence and gradual abrasion at successive levels; and that of the formation of open chasms towards the close of the same period, when the country reached its greatest elevation as dry land.

Along the entire line of the Haldons just described, there is abundant evidence of a great rise of the beds to the east; and the amount of this elevation is best ascertained by the relative position of the greensand deposits of Haldon and Bovey, which must have been at the same level, and under precisely similar conditions, when formed. The height of Little Haldon above the sea at Teignmouth is 890 feet; but at least half the thickness of the greensand of the Bovey valley must be below the level of the sea, so that there is a difference of 800 feet in the present positions of beds once continuous. This elevation took place perhaps slowly, but at the same time with that general rise of all the south of England, which happened towards the close of the tertiary period; and it is possible that previous to this event the whole was submerged as far as the high lands of the west of England; and I believe it was then that the pebbles of granite, schorl and quartz were distributed over what are now the summits of the Haldon and Blackdown hills.

Subsequent to this period of denudation, and under the same conditions with the fissures of the limestones, were formed those great fractures along one of which the Teign flows as far as Chudleigh, also the parallel valley from Bovey to Moreton, and the origin of which was evidently connected with the numerous abrupt movements that produced the deep valleys in the granitic region of Dartmoor, and which, being but little above the level of the sea, can have no great antiquity, as they are unoccupied by any sedimentary accumulations.

The lower part of the course of the Teign, like that of the Exe and many other streams, is through a valley of excavation along a line of fault; its course is due east and west, and it will be seen that the mouth of the Teign is the only point along the coast-section of the new red sandstone formation, where the strata have an anticlinal dip to the north and south (Map, Pl. XLI.). Higher up the valley, and on the north bank, opposite Combe-cellars, is a fault which for more than half a mile, in an east and west direction, brings up the slate in vertical juxtaposition with beds of new red sand; the downcast, as usual, being to the west, but the

amount uncertain. Nearer Teignmouth the same fault may be traced through some conglomerate beds; and westward it ranges along the foot of the cliff of greenstone opposite Hackney claycellars, by Newton; and from Bradley to Holbeam Mill it traverses a great mass of limestone, in a zigzag course, owing to the rock having yielded alternately along its two sets of joints; beyond this it cuts a line of hill, consisting of slate with trap dykes: the direction of the hill is diagonal to the direction of the fault, which passes through at a right angle, but immediately resumes its course along the valley of the Lemon; still further it breaks the band of limestone below Bickington, then enters the carbonaceous deposits, and may perhaps be connected with some of the east and west faults, which, as at Owlecombe, become metalliferous as they approach the granite beneath Rippon Tor.

At Bickington and along its whole course (see map), the displacement of strata, both vertically and horizontally, is very remarkable, the beds on the north side of the fault being apparently shifted to the east.

The faults exhibited in the cliffs of Dawlish (Pl. XLII. fig. 5.) range westward in their inland course, and the lower beds of greensand on the Haldons are put at different levels, by faults having a like direction, and which traverse the superficial beds.

It appears therefore, that the more recent disturbances had a general east and west direction. In the description of the granitic region of Dartmoor it has been stated that very many of the lines of hill and valley, instead of conforming to the range of the several masses of Cornwall and Devon, have courses from north to south; and many of these lines of elevation extend from the granite into the area of the carbonaceous deposits on the north. The Haldon hills are on a line due north and south, and the proofs of elevation observable along the western slope have already been noticed; it was this disturbance which also opened the north and south joints of the limestone; and, parallel with the Haldons, is the greensand escarpment of the Blackdowns.

The course of the Exe, as low down as the head of the estuary, where it falls into another line of disturbance, is along a most extraordinary north and south dislocation, which, like the east and west fault already described, has severed beds once continuous, and to a much greater extent: numerous faults with the same direction range through the Blackdown hills*.

The character which principally distinguishes this system of faults, apart from direction, is the very great amount of vertical movement which the beds to the east experienced; thus we have seen that the greensand of Haldon acquired an elevation of 800 feet above that of the Bovey valley; and the displacement along the course

* This system of faults, which affects in a remarkable manner the Blackdown range and adjacent districts, was traced out and first described by Mr. De la Beche, in his 'Researches in Theoretical Geology,' and subsequently in his valuable 'Report on the Geology of Cornwall and Devon.'

of the Exe must also in places be very great. This system of faults, producing an upcast to the east, is proved to be referable to the tertiary period, by the beds which it traverses; and the movement was probably attended or produced by those causes which converted into dry land what before was covered by water, and imparted an uniform elevation to a great portion of the south of England, without reference to geological age.

The condition of things which had so long favoured the production of calcareous beds, and had allowed time for the segregation of the layers of flint, as well as the slow conversion of the calcareous shells and corals into siliceous casts, was succeeded by the partial destruction and removal of the chalk, whilst the uninjured state of the flints, which remain in place, shows that the process could not have been a violent one. That period of destruction immediately preceded the true commencement of the tertiary epoch, during which siliceous sands of considerable thickness were accumulated, and those internal changes took place whereby the siliceous breccias and grey-wethers were produced. To this again succeeded another extensive period of destruction and removal; the whole constituting a succession of events which indicate very variable conditions over the same place, and imply a long lapse of time.

The interval between the completion of the older series of rocks and the commencement of the new red sandstone period must have been very great. The early deposits, originally consisting of mud, ooze, or sand, had been placed in conditions by which great internal changes of structure and arrangement were superinduced; for in the materials which compose the lower new red conglomerate beds, we have abundant evidence that when the abrasion commenced from which the conglomerates resulted, the older deposits had passed into the same condition of compact siliceous rocks, fissile slates, and crystalline limestone which they now present.

We can never hope to know enough of the rate of increase of deposits at present in progress to serve as a guide in the important question of the lapse of time during geological periods; but as accumulations can only proceed *pari passu* with destruction and removal, it is perhaps in the action of breakers and the waste along our coasts that we have the most available means of approximating to the vast series of years during which our several formations were in progress; but of the intervals which elapsed from one to the other we can form no conjecture.

In certain instances destruction has been local, and evidently exerted over the same spot for a long continuance; thus the limestones of Babbacombe still preserve their massive tabular character; but close by, as at Petit Tor, the calcareous strata have been reduced to a few feet in thickness, of which the breccia is all that remains.

A very remarkable line of elevated strata, with a direction west 30° north to east 30° south, crosses the west of Devon, from Hope's Nose on the east of Torbay to

Stoke on the north coast of the county; and all the streams are thrown off on each side of the line. The high inclination of the limestone of Torquay and Chapel Hill is owing to this disturbance. The same direction is repeated in many places, including the boundary-line of the granite, from near Oakhampton to Botter, which runs parallel with it. The most striking line of depression apparently belonging to this system of disturbances, crosses the county from Barnstaple on the north to the broad estuary of the Exe on the south. The coast section, near the Tor Abbey Sands, shows that by this disturbance beds of new red sandstone were thrown into a vertical position.

Again, before the commencement of the new red sandstone period, these older strata experienced disturbances which produced an irregular outline of surface, and which, even in this limited district, have a very striking parallelism. The line of limestone cliff against which the new red conglomerate terminates, from Whiddon to Kingskerswell, ranges due east and west, as does the ridge of highly inclined limestone which protrudes through the new red conglomerate between Kingskerswell and Barton, and which was evidently thrown into its present position before the conglomerate strata were formed around it. The other protruding masses, as at Compton, Gallowsgate, and above Stanton, indicate the very unconformable condition of the two formations. Masses of limestone in places skirt the north and south edges of the red sandstone areas, as from Bulley Barton to Bowhill, and from Marldon to Wickaborough; and the whole of this portion of the new red sandstone area from Tor Moham to Bow Bridge*, as also that from Paignton to Blagdon, extend from the coast inland from east to west. The horizontal or slightly inclined position of these beds on the edges of the older red slates and sandstones may be observed in coast-sections in Torbay.

Further, the metamorphic rocks from the Start Point to the Bolt Head have been elevated along a line due east and west, and this disturbance apparently extends westward to the Eddystone rock, which is mineralogically the same with that at the Prawle Point. A valley corresponds to this line of crystalline rocks on the north, running from Start Bay to Bigbury Bay on the west, and at both openings of this valley with the sea, beds of new red conglomerate occur.

In the north of Devon and the adjoining parts of Somerset the older strata were also raised along an east and west line about the close of that period. In Morte Bay, where so many curious facts are to be observed, large blocks of igneous rocks are scattered over the beach, precisely at the place where the cliffs show that the strata have been greatly disturbed and altered. Lundy Island is placed on a line prolonged due west from this point, and as granite here throws up similar beds, it is

* The relative positions of the slate rocks and new red sandstone beds at this place, as seen in the road-section, require an east and west fault of considerable amount.

possible that to some extent, both in Devon and Cornwall, granite approached the surface during this comparatively early east and west disturbance. Some of the blocks on the beach in Morte Bay resemble the red porphyry of Exeter, which certainly belongs to the close of the carbonaceous period.

Parallel to the range of the older strata in North Devon and the west of Somerset there occurs in South Devon a line of elevated fossiliferous beds extending from Tintagel to Tavistock, and forming the southern boundary of the carbonaceous deposits.

The conditions suggested by the consideration of the great slate system of the west of England are those of slow and tranquil deposition, and an uniform condition as to depth; and the delicate markings which the casts of the various shells preserve, indicate the minute state of the sedimentary matter. We can never expect to ascertain the amount of dislocation and disturbance which such a system has experienced, owing to its uniform mineral character; but as we know, that in this very district, all the newer formations present such phænomena on a large scale, and that such disturbances have been propagated from below, the lowest deposits should exhibit the sum-total of the disturbances of every geological period.

The included limestone bands, as at Knowle, Broadhempston, and Little Hempston, of which a representation is given at fig. 9, Pl. XLII., will show that with the apparent uniformity, the result of cleavage, there may be much disturbance. The faults and contortions of the coral limestones may be observed in every quarry, and some instances in the neighbourhood of Torquay have been represented in the third volume of the Geological Transactions* by Mr. De la Beche. Near Broadsands in Torbay the red slates include a vein or bed, apparently composed of limestone pebbles; and though both the ground-plan and vertical section show it to be broken and heaved in several places, yet at a short distance on either side, it would be impossible to detect the disturbance.

It has been suggested (see *antè*, p. 477) that portions of the granite of Dartmoor may be of different ages: it certainly has partaken of all the disturbances of the district subsequent to those of an early period, with an east and west direction; and the highest portion, such as that of the Cawsand group, seems to occur at the intersection of two lines of elevation. The trappean bands of the slate system of South Devon and Cornwall; their abundance along the north skirts of Dartmoor, interstratified with beds which certainly were deposited before the intrusion of any granite; the remarkable lines of erupted trap on the south, running parallel with the present granitic axis of the county, and becoming less frequent as we recede from it, till in the southern slate district they are nearly wanting; and the great porphyritic mass of Exeter, at the eastern extremity of the same line, seem to indicate the continuance of igneous action along the same line, and through a vast period of time.

* Pl. XVIII. figs. 3, 4, and Pl. XIX. figs. 1, 2.

XXIX.—*On the Characters of the Beds of Clay immediately below the Coal-Seams of South Wales, and on the occurrence of Boulders of Coal in the Pennant Grit of that district.*

By WILLIAM EDMOND LOGAN, Esq., F.G.S.

[Read February 26, 1840.]

IN South Wales, immediately below every regular seam of coal, and coextensive with it, lies a bed of clay, which is commonly called underclay, underclift, understone, bottomstone, or pouncing. It is of so peculiar a character, and the miners are so well acquainted with it, that there is scarcely one who would not immediately recognize a specimen of it, and state its position in relation to the coal.

From several sections made with care in various places, it has been clearly ascertained that the coal-measures of South Wales, from the mountain limestone upwards, attain in the deepest part the great geological thickness of 12,000 to 13,000 feet. They contain nearly 100 thick and thin seams of coal, about one half of which, measuring a foot and upwards in thickness, have in various places been more or less worked, and I am not aware of a single instance of a seam unaccompanied in any part by this subjacent bed; indeed so thoroughly is the Welsh miner persuaded that the two things are essentially conjoined, that he would as soon expect to live in a house without a foundation as to work in a coal-seam which did not rest upon underclay. It is very necessary that he should be familiar with the material, as it occasionally serves a most important purpose in prosecuting the work of a coal-mine; for though there is never coal without a subjacent bed of underclay, there is sometimes underclay without superincumbent coal. A seam of coal which becomes thinner by degrees will occasionally vanish altogether; but, after a short distance, it will appear with increased thickness, and ultimately regain its original dimensions. When a collier, meeting with an irregularity of this description, perceives the coal disappear, he might find it difficult to know whether he had not suddenly come upon a fault completely dislocating the measures, if he had not the underclay to guide his course; and it is only when this fails, that he feels assured, the direction of his search must be changed.

This underclay, as its name imports, is generally more or less argillaceous, but it is never without a considerable admixture of sand; and it is always of a fine

texture, yielding in most cases a very good fire-clay*. In many parts of the coal-deposit of South Wales, it is tough, though not very hard, when fresh cut, but on exposure to the weather it slacks, splits, and crumbles into a greyish mass. It is occasionally quite black, from an admixture of carbonaceous matter, and is then sometimes sufficiently consistent to resist the effects of weather; and under some of the lowest seams of coal between Swansea and the Bury river, it yields a hard, durable, fine-grained, siliceous stone, very much resembling quartz rock†.

It is not, however, by the mineralogical composition that these beds are so thoroughly marked, for they not only vary considerably, but many strata occurring in other parts of the coal-measures, are precisely identical in mineral contents. The grand distinguishing feature of the underclays is the peculiar character of the vegetable organic remains: these are always of one kind (*Stigmaria Ficoides*), and are so diffused throughout every part of the bed, that by their uniform effect alone the clay is readily recognized by the eye of the miner.

The beds, varying in thickness from six inches to more than ten feet, and averaging about three, are crossed and penetrated vertically, horizontally, and obliquely, by a confused and tangled collection of long, slender, fibrous casts, with a thin coating of carbonaceous matter. These fibres are sometimes cylindrical, though generally flat, and are usually about a quarter of an inch in breadth; but they are very often traceable to a junction with a stem or branch, sometimes flattened, sometimes not, and varying in diameter from about two inches to half a foot. From this stem or branch, which is usually of considerable length, and always lies in the plane of the bed, but rather nearer the top than the bottom, the fibres radiate in all directions, and take such a tortuous irregular course that it is impossible to follow any one of them to the natural termination, though it is easy to see that the range is very considerable. This fossil, the *Stigmaria Ficoides*, taking for granted that the slender fibrous impressions belong always to it, so completely fills every bed of underclay, that it is not possible to cut out a cubic foot which does not contain portions of the plant. It is also worthy of remark, that specimens with the fibres emanating from the stem or branch are to be discovered only in the underclay.

It is proper, however, to state, that such specimens, even if they did exist in other

* It usually makes a good fire-clay when free from nodules of ironstone, which however are generally disseminated in great abundance through it.

† Not far from Penclawdd, on the Bury river, there is a seam of coal called the *Farm Seam*, the bed beneath which is a grit or sandstone, and I should think sufficiently durable to be used for building purposes. On first seeing it I was disposed to consider it an exception to the general rule of underlying beds, but on breaking it across the plane of the bed I found it penetrated, like all the rest, by the long fibrous processes of the Stigmaria, though not quite in the usual abundance.

beds, are not so likely to become exposed in them; whereas the operations of extensive collieries naturally afford the opportunity of making vast collections from the underclays; for when a coal-seam is either throughout or partially too thin to permit the excavation of the coal without the removal of some portion of the ground in juxtaposition to it, the superior softness of the floor induces the miner to make the required cuttings in it rather than in the ceiling; or when it becomes necessary to obviate the effects of a "creep" in any of the roads, it is again the floor that is pared down, and in these and other ways a large amount of specimens in the underclays is exposed. Sometimes however the ceiling of one coal-seam is the floor of another, and in such instances, if the collector were on the lower bed, he might discover above him specimens that would appear to contradict what is above stated as a general rule, while it is obvious, an attentive examination of the case would only confirm the truth of it. That bare stems or branches of Stigmaria have been found in other beds there can be no reasonable doubt, indeed it would be very surprising if many such instances did not occur; for even if the underclay were the natural and original site of the plant, specimens must have been occasionally washed out of their first position and deposited in some superior bed at the time of forming.

The *Stigmaria Ficoides* is described by all those who have written on the subject as the most abundant plant of our carboniferous series; but no one has given a fuller account of the localities in which it is found, of the external botanical character it bears, and of the attitude it generally presents *in situ*, than Mr. Steinhauer in the American Philosophical Transactions; and his description is so applicable to the condition of the plant in coal strata, which for the last seven years have been the constant object of my own investigation, that I shall quote a part of his description*. (New Series, vol. i. p. 265 *et seq.* 1818.)

He says, "It is most abundant in the fine-grained siliceous stone provincially called *Calliard* and *Gannister*, and in some of the coal-binds or crowstones. It is rather less frequent in the beds of scaly clay, or clay mixed with siliceous sand and mica; very common but completely compressed in the coal-shales or bituminous slate-clay; of occasional occurrence in the argillaceous ironstone; not rare in the common grit and upper thick beds of argillaceo-micaceous sandstone or rag; and sometimes, though rarely, discoverable in the coal itself."—"The most perfect form in which this fossil occurs is that of a cylinder more or less compressed, and generally flatter on one side than the other. Not unfrequently the flattened side turns in so as to form a groove. The surface is marked in quincuncial order with pustules, or rather depressed areolæ, with a rising in the middle, in the centre of which rising a minute speck is often observable. From different modes and degrees of compression, and probably from different states of the original vegetable, these areolæ assume very different appearances; sometimes run-

* Notwithstanding the closeness with which Mr. Steinhauer must have examined the Stigmaria beds, the unvarying relation of the coal-seams to them does not appear to have struck him.—*March* 1842.

ning into indistinct rimæ, like the bark of an ancient willow; sometimes, as in the shale impressions, exhibiting little more than a neat sketch of the concentric circles."

In speaking of the fibres connected with these centre cylinders, Mr. Steinhauer remarks, "We were soon able to detect their remains, forming considerable masses of stone, particularly coal-bind, on Webbsey Slack, and at Lower Wyke, where their contorted figures imitate those of Serpulæ; but it excited much surprise, on examining the projecting ends of some trunks which lay horizontally in a bed of clay extending along the southern bank of the rivulet which separates the townships of Pudsey and Tong, and which is exposed in several places, to find traces of these fibres proceeding from the centre cylinder in rays through the stratum in every direction to the distance of twenty feet. Repeated observations, and the conviction of unprejudiced persons made attentive to the phænomena, compelled the belief that they originally belonged to the trunks in question, and consequently that the vegetable grew in its present horizontal position at a time that the stratum was in a state capable of supporting its vegetation, and shot out its fibres in every direction through the then yielding mud. For if it grew erect, even admitting the fibres to have been as rigid as the firmest spines with which we are acquainted, it would be difficult to devise means gentle enough to bring it into a recumbent posture without deranging their position. This supposition gains strength from the circumstance that they are found lying in all directions across one another, and not directed towards any particular point of the compass."

Excepting that I never saw a mass of fibres extend to a vertical distance of more than seven or eight feet from the centre cylinder, although I believe it may range to twenty and more horizontally, the latter part of this quotation describes very fairly the general attitude in which every specimen is discovered in the underclays of South Wales; and when it is considered, that in so wide a district of country abounding in coal, there is not a seam which is not immediately underlaid by a bed wholly monopolized by these peculiar vegetable organic remains, it is impossible to avoid the inference, that some essential and necessary connection exists between the production of the one and the existence of the other. To account for the unfailing combination by drift, seems an unsatisfactory hypothesis; but whatever may be the mutual dependence of the phænomena, they give us reasonable grounds to suppose that in the *Stigmaria Ficoides* we have the plant to which the earth is mainly indebted for those vast stores of fossil fuel which are now so indispensable to the comfort and prosperity of its inhabitants*.

* It was in the summer of 1837, when Mr. De la Beche was about to commence his survey of the district, that I first pointed out to him the constant presence of the Stigmaria beds beneath the coal-seams of South Wales, and his subsequent and more extended examinations have, I believe, fully confirmed my own observations. Since then and since this paper was read, I have visited several other coal districts, but have found no decided contradiction to any of the facts which South Wales presents. In a tour through Pennsylvania in the United States of America, in August and September 1841, I detected these beds under the coal-seams of the anthracite regions at Pottsville, Mauch Chunk, and particularly in the coal-field of Wyoming, also at Wilkesbarré on the Susquehanna, where I remained long enough to make a detailed section across the northern anthracite basin. These beds were, with one doubtful exception, very strongly marked, and I saw and touched them beneath upwards of thirty coal-seams, great and small, and in several parts of the district widely asunder. From what I learnt in personal com-

I have stated (p. 491) that the coal deposit of South Wales, from the mountain limestone upwards, attains, in the deepest part, the enormous thickness of 12,000 feet. It will naturally occur to every one, that the accumulation of such a vast amount of material would require the lapse of a great period of time, and as any fact which can afford a probable measure of the comparative extent of such a period must possess some interest, I shall take this opportunity of mentioning one that bears on the subject.

From the top of a seam of common bituminous coal, about five feet thick, at Penclawdd, on the Bury river, I obtained, in the spring of 1833, a small, worn or rounded boulder of cannel coal, six inches long, four inches wide, and two inches thick. It was almost wholly imbedded in a layer of indurated clay two inches thick, interposed between the coal and the regular roof of hard sandstone, and which touched the upper side of the boulder. After the discovery of this singular specimen, attention was awakened to the subject, and it was found that in the quarries excavated in the enormous deposit of sandstone forming Cilfay Hill and the town hill range from Swansea to the Bury river, there occur many irregular beds of what, from the innumerable pebbles and small boulders of coal aggregated in them, may be termed a coal conglomerate. The coal pebbles are sometimes four inches in diameter, and are confusedly mingled with sand and pebbles of ironstone; and associated with them have likewise been found small boulders of granite and mica slate. Many casts of Sigillariæ and other plants, coated with coal, occur in the mass; and the difference in the age of this coal and that of the pebbles is beautifully illustrated in numerous cases, where the plants have been pressed down on a layer of coal pebbles, which, from their superior hardness, have penetrated into the plants, and thus the newer and older coal have been brought into juxtaposition; but the crystallization of the former, however distorted the plant may have been,

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munication with some of the gentlemen attached to the geological survey corps of the State, I am persuaded they exist with equal constancy under the coal-seams of the great Pennsylvanian bituminous district; and I was informed by Dr. Rogers, whom I had the pleasure to meet in Philadelphia, that they are found in the same relation to the coal in its prolongation in Virginia, with the geological survey of which his name is so eminently connected.

In a visit made immediately afterwards to some of the coal districts of Nova Scotia, and particularly to that in the neighbourhood of Pictou, near which the Albion mines are worked, I had an opportunity of seeing these Stigmaria beds under upwards of a dozen of coal-seams; and I was informed by Mr. Poole, who superintends the Albion mines, that similar underlying beds exist in the Cape Breton Island coal-field, where he formerly managed the Bridge Port and Sidney Mines.

Since my return from America I have visited coal-seams in the neighbourhood of Falkirk in Scotland, and found under them the Stigmaria beds; I have also evidence that they are in the same way associated with the coal-seams of Ayrshire, where they go by the name of "Fakes".—*March* 1842.

presents a uniform parallelism in the faces of its cleavage, while the cleavage of the older coal is parallel with the sides of the pebbles, which lie in all positions, and very often exhibits the form of a rhomboid with its edges and corners rounded by attrition. The coal of the pebbles, like that of the regular seams in the neighbourhood, is of the common bituminous kind, but among them have been found two small ones consisting of cannel coal.

The Cilfay sandstones, and the measures at Penclawdd, in which the first-mentioned pebbles were found, form part of the Pennant grit of Mr. Conybeare, and there is reason to believe that throughout the whole of this great mass of sandstone, in thickness about 3000 feet, there are occasionally beds of coal pebbles.

I have not seen any of them associated with the lower seams. If none exist, it might be inferred that the pebbles in the Pennant grit were derived from them, after the coal-beds of the lower measures had been indurated, converted, and crystallized. Now as the only beds of cannel coal in the lower measures, to yield the pebble found at Penclawdd, are two or three lying about 2000 feet below the coal-seam, it follows that the deposit of these 2000 feet must have required at least the time necessary to convert vegetable matter into good pit-coal; and if it is not assuming too much to suppose that the deposit proceeded at an equal rate from the beginning to the end, six times that period must have elapsed before the accumulation of the whole coal-field of South Wales was completed.

APPENDIX.

Section of Coal-measures at Pembray, in Caermarthenshire, South Wales.

	Ft.	in.
Sandstone or grit, hard and micaceous	45	0
Arenaceous shale	30	0
Sandstone as before	32	0
Arenaceous shale	1	6
Sandstone	1	0
Arenaceous shale	2	6
Sandstone	39	0
Argillaceous shale with a continuous band of ironstone 1 inch thick	3	0
Sandstone	48	0
Argillaceous shale with a continuous band of ironstone 2 inches thick	2	0
Coal and carbonaceous shale in thin alternate layers	4	0
Underclay filled with *Stigmaria Ficoides*	2	0
Arenaceous shale	0	6
Coal	0	1
Underclay filled with *Stigmaria Ficoides*	2	6
Argillaceous shale with a slight quantity of sand in it	11	6
Coal and carbonaceous shale in alternate layers	1	0
Underclay with Stigmariæ	1	6
Argillaceous shale	14	6
Coal	0	5
Underclay with Stigmariæ	1	0
Argillaceous shale	7	0
Coal, bituminous. [This and the set of seams near it are called the Gwdig seams.]	0	10

	Ft.	in.
Underclay with Stigmariæ	5	6
Argillaceous shale	1	0
Coal	0	1
Underclay with Stigmariæ	5	6
Arenaceous shale	7	0
Carbonaceous shale	0	1
Underclay with Stigmariæ	2	0
Arenaceous shale	2	6
Sandstone	90	6
Arenaceous shale	2	0
Sandstone	7	0
Clay, and a black carbonaceous-looking matter with an uncertain underclay	2	0
Arenaceous shale with nodules of ironstone; the lower part is soft	15	0
Argillaceous shale	13	6
Sandstone	27	0
Arenaceous shale	1	9
Sandstone	44	0
Argillaceous shale	2	0
Sandstone	50	0
Argillaceous shale; soft towards the bottom	28	0
Coal, with a small band of carbonaceous shale in it. [This seam is called the Gwscwm, and is extensively worked near Pembray.]	3	0
Underclay, with Stigmariæ in abundance	4	6
Coal	0	6
Underclay with Stigmariæ	1	0
Sandstone	6	0
Argillaceous shale	16	0
Arenaceous shale	8	0
Sandstone	2	0
Arenaceous shale, very hard	13	6
Sandstone	1	0
Arenaceous shale	9	0
Sandstone	12	6
Coal, bituminous	0	9
Underclay with Stigmariæ	1	0
Arenaceous shale	6	6
Coal, bituminous; called the Ringog Fach seam	1	2
Underclay with Stigmariæ	2	2
Argillaceous shale, some parts slightly arenaceous	35	0
Coal and carbonaceous shale in alternate layers. The coal is bituminous, and the seam called the Ringog Fawr is worked at the extremity of Pembray mountain	3	0
Underclay with Stigmariæ	2	0
Coal, bituminous	0	8
Underclay with Stigmariæ	5	0
Sandstone	98	0
Arenaceous shale	2	0
Sandstone	24	0
Arenaceous shale	2	0
Sandstone	84	0
Argillaceous shale. In this are found impressions of Ferns in fructification	8	0
Sandstone	20	0
Argillaceous shale	1	6
Sandstone	66	0
Arenaceous shale	4	6
Sandstone	57	0
Coal, without underclay	0	4
Sandstone	136	0
Coal, bituminous, with a thin band of carbonaceous shale in it. [This seam is called the Kenrhos, and has been extensively worked.]	4	6
Underclay filled with Stigmariæ	5	6
Arenaceous shale	15	0
Argillaceous shale	8	0
Sandstone	3	0
Arenaceous shale, with four bands of sandstone, each about six inches	26	0
Sandstone	17	0
Coal	0	6
Underclay with Stigmariæ	2	6
Argillaceous shale	3	6
Coal	0	11
Underclay with Stigmariæ	2	6
Argillaceous shale	3	0
Coal	0	8
Underclay with Stigmariæ	4	0
Arenaceous shale	38	6
Coal and carbonaceous shale in alternate thin layers	6	0
Underclay with Stigmariæ	4	0
Arenaceous shale	13	0
Coal, bituminous, Upper Cœd Rhial seam	1	6
Underclay with Stigmariæ	4	0
Arenaceous shale	17	6
Argillaceous shale	7	0
Coal, bituminous. [This is called the Lower Cœd Rhial seam.]	2	6
Underclay with Stigmariæ	3	0
Argillaceous shale	5	6
Arenaceous shale	25	0
Argillaceous shale	3	6
Arenaceous shale	12	0
Coal, bituminous	1	2
Underclay with Stigmariæ	3	6
	1239	9

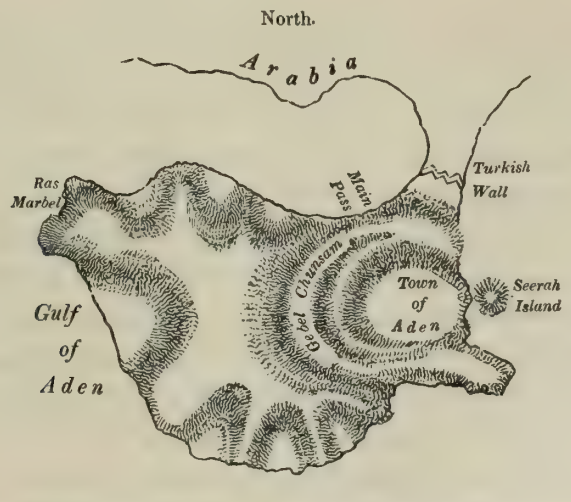
XXX.—*Sketch of the Geology of Aden, on the Coast of Arabia.*

By FREDERICK BURR, Esq.

Communicated by JOHN TAYLOR, Esq., Treas. G.S.

[Read January 6, 1841.]

It is not I believe generally known to English geologists, that we have now within the limits of the British dominions perhaps the finest example in the world of extinct volcanic action—I allude to Aden, our new settlement on the coast of Arabia, where I had an opportunity of spending a short time in the early part of the present year. Imperfect as the following description, the result of hasty examination, may be, it will still embrace a few principal facts respecting this interesting locality, and serve at the same time to direct towards it the attention it so well deserves.



The promontory of Aden is situated about eighty miles eastward of the Straits of Bab-el-Mandel, in latitude 13° north; and it consists of a bold cluster of volcanic rocks rising into lofty and jagged peaks, which are connected with the main land of Arabia by a low sandy isthmus. The extreme length of the promontory may be about six miles, the breadth half as much. The loftiest and most prominent portions of the whole mass are volcanic, and the lower portions are partly volcanic also, but exhibit many beds of consolidated sea-sand, which have been more or less ele-

vated above the general level of the ocean. The most interesting portion of the promontory is however an immense volcanic crater, which is situated at the extremity next the main land, and in the very centre of which the town of Aden with the British cantonment stands. This magnificent crater is nearly circular in form; its diameter is probably about a mile and a half, and it is surrounded on the northern, western, and southern sides with precipices chiefly composed of lava, and rising from 1000 to 1776 feet in height, the latter elevation being that of the "Gebel Shunsam," a lofty range of volcanic peaks, which form the crater's western side. On the eastern side the wall of the crater has subsided or been broken down for about half a mile, thus allowing the sea to come almost close to the town, and forming a small bay, generally occupied by native Arab vessels. Still however the lofty and abrupt island of "Seerah," about the middle of the gap, serves as it were to connect the broken portions, and almost to complete the original circle of the crater. Northward of this great focus of eruption, and ranging to the extremity of the promontory, is an immense mass of lofty and jagged rocks, all composed of lava. They have indeed much the appearance of a cluster of smaller volcanic craters, the sides of which have been washed away to the eastward by the action of the sea; but on this portion of the promontory, I was able to bestow but a slight and hurried examination.

The interior of the great crater in which the town of Aden stands, presents almost a flat surface, and is not elevated very much above the sea-level, the volcanic orifice appearing to have been filled up so far, partly by the crumbling in of the sides, and partly by the matter which may have washed in from the sea. The crater itself, though at first sight almost perfect, has manifestly undergone some rude shocks, the effects of which are very apparent on examination. It has in fact been cleft entirely through in one direction and partially so in another; a great fissure ranges across it from north to south, and the two rents formed by it in the walls are called the "northern" and "southern passes," the former of which being very important in a military point of view, as it affords the principal ingress, is strongly fortified. The western half of the crater stands entire, forming the "Gebel Shunsam," which, as already noticed, is 1780 feet in height, and has within it a curious ledge of rocks about half its own elevation, which I had not time to examine. The eastern half of the crater has evidently undergone a partial subsidence; as it does not rise to more than half the height of the western side, and it appears to have separated in two parallel lines at right angles to the great north and south fissure. It is on the line of these subordinate fissures, that the sea, as before noticed, has broken in, and between them stands the island of "Seerah," which, although left as it were without support on both sides, has itself very slightly subsided.

While viewing the grand disruptions of this great volcanic mass, which although

of commanding altitude and several miles in circumference, has evidently subsided, like a cottage undermined by a neighbouring stream or river, I naturally looked back to the great catastrophes which had happened on the spot, and endeavoured to determine their nature. The volcano itself may probably have been submarine in the first place, and successive eruptions may have gradually elevated it above the level of the sea. After this its paroxysms appear to have become less violent, as otherwise the sides of so vast an orifice might have attained a much greater elevation than 1700 or 1800 feet. From the great subsequent subsidence on the eastern side, it would appear that in that direction the volcano had been gradually undermined, till at length it cracked from north to south, and the subsidence of the eastern half took place. This enormous mass, however, in subsiding seems to have cracked again into three portions by fissures at right angles to the direction of the principal movement. The subjoined woodcut will render this explanation more clear, and make it better understood.

Such appearing to be a brief outline of the physical history of this volcano, the eruptions of which were probably accompanied by the throwing up of smaller cones to the northward, I shall now briefly advert to the various rocks which compose the promontory of Aden, and the phænomena they present. The rocks which I observed were the following :—A dark brown or chocolate-coloured lava, generally of a very cellular texture, which is by far the most abundant rock. It forms all the high peaks of the promontory, as the "Gebel Shunsam," the upper part of "Seerah" Island, and the bold cluster of rocks at the northern extremity, called the "Ras Marbel," and it in many places constitutes the whole mass down to the sea level. This enormous accumulation of lava is sometimes, especially on the east side of the great crater of Aden, separated in the middle by a very thick bed of greenish porphyry, having generally a slightly lamellar structure. This porphyry is itself interstratified with red ochreous beds, which occur also between it and the lava, and appear to be derived from either decomposed lava, or from showers of volcanic matter, afterwards converted into an ochreous clay. Near the "northern pass" I observed a curious granular rock, probably a volcanic breccia; but having lost the specimens I collected, I am unable to describe it with any precision. Apparently at the base of all the above rocks, there are in places, especially near the "northern pass," thick beds of slightly consolidated sea-sand, which seem by their diagonal stratification to have been drifted by opposing currents, and may probably have formed the bed of the sea, when this great submarine volcano first broke forth. In the northern part of the promontory, the flat line of coast, between the volcanic peaks on the one side and the sea on the other, is evidently merely a raised beach, where the loose sea-sand is consolidating into a tolerably compact sandstone, owing to the action of a tropical sun upon the calcareous matter of the sand. This for-

mation of recent sandstone is further interesting from its inclosing numerous existing shells and corals of the adjoining Arabian sea. As regards the stratification of the rocks here described, the porphyries and volcanic products have generally an inclination of about 15° *from* the crater, but in some places their position is irregular and contorted.

Independently of the great fissures and lines of subsidence before noticed, the volcanic rocks of Aden present numerous and striking examples of dykes raking through them like walls, and generally almost perpendicular. These dykes appeared to me to be chiefly filled with siliceous matter, and to be both harder and more compact than the adjoining volcanic rocks. The most prominent and remarkable of them is one near the "main" or "northern pass"; it is several feet wide, and has almost the appearance of a vast wall crossing the mountain. Other conspicuous dykes are seen in "Seerah" Island, cutting through both the beds of porphyry and lava. I observed in many places small veins of chalcedony intersecting the lava.

Some pieces of black and green obsidian from the volcanic rocks of this promontory were kindly given to me by Dr. Malcolmson; but I did not see the places where they were collected, nor learn the circumstances under which they were found. The green obsidian is quite glassy in its texture, and in some of the specimens the colour is very pale. One piece is very interesting, the obsidian itself running in small veins to a coarse cellular trachytic rock, and suggesting the idea of materials of very unequal fusibility, having been exposed together to the intense heat of the volcano, the result being a segregation of the most fusible portions, and the melting of them into obsidian, while the adjacent refractory matter has undergone but little change.

The above hasty sketch of this interesting tract is given as an imperfect outline only; but should this port be abandoned, even these rough notes may become valuable, as no European could then visit this spot. Should, on the other hand, the settlement be retained, the present notice may attract the attention of future travellers who may have more leisure to examine the promontory of Aden. I would remark, in conclusion, that few contributions to geology would be more valuable than an examination not only of Aden but of the other volcanic groups, some of them as yet hardly extinct, which extend north-westward from that promontory through at least the southern portion of the Red Sea.

Madras, July 1840.

XXXI.—*On the Teeth of Species of the Genus* Labyrinthodon (Mastodonsaurus *of Jaeger*), *common to the German Keuper formation and the Lower Sandstone of Warwick and Leamington.*

By RICHARD OWEN, Esq., F.G.S., F.R.S., &c.

[Read January 1841.]

WHETHER the light-coloured sandstone of Warwick be, as Dr. Buckland conceives, the equivalent of the German Keuper, or, as Messrs. Murchison and Strickland contend, of the Bunter-sandstein, was a question which awaited the evidence of organic remains for its decision. For, notwithstanding the nature and number of the lithological characters collated by them, the latter authors do not insist upon this as evidence decisive of the accuracy of their views, but are willing to set the determination of the question upon the issue of organic remains, nay even of a single Saurian.

"If it could be shown," say Messrs. Murchison and Strickland, "that the fossils which we have pointed out as characterizing the upper sandstone, occurred also in the lower,"—"and that the fragments of Saurians found in the sandstones of Guy's Cliff and Warwick really belonged to the species peculiar to the Keuper,—then, indeed, we should willingly allow that the lower sandstone *also* must be grouped with that formation*."

The fossil reptiles which chiefly characterize the German Keuper are of the genera *Dracosaurus* and *Mastodonsaurus*; the former belonging probably to the Saurian order; the latter being undoubtedly a huge Batrachian, hence originally called '*Salamandroïdes*' by its discoverer Professor Jaeger. It is the evidence of the existence of remains of a species of the same peculiar extinct Batrachian genus in the lower sandstones of Leamington and Warwick, that I now propose to lay before the Society.

The genus *Phytosaurus*, also called *Cylindricodon* and *Cubicodon*, is perhaps most familiar, by name, to English geologists†, as a Keuper fossil: it is, however, merely a nominal genus, being founded on the socket of the tooth of some other reptile.

* Geol. Trans., 2nd Series, vol. v. p. 345.

† From the circumstance of its supposed existence in the Wealden formation.

The extremity of the portion of matrix, moulded to the bottom of the socket, having been mistaken for the grinding surface of the tooth, suggested, from its presumed adaptation to crush vegetable substances, the name of *Phytosaurus*. One of the supposed teeth of this reptile has been transmitted to me by Prof. Jaeger, which, upon examination, proves to be a mineral cast.

With respect to the term *Mastodonsaurus*, it has been already objected that it unavoidably recalls the idea of the Mammalian genus *Mastodon*, and not the teat-shaped tooth assumed to be the distinctive character of the genus which the name was invented to express. But there are other and graver objections to the term *Mastodonsaurus*: the rounded and obtuse summit of the crown is an exceptional, not a constant termination of the teeth of this genus, for every tooth in the jaw is originally, and the greater number are permanently, of a cuspidate and not of a mammilloid form. And if the first part of the compound name *Mastodonsaurus* thus conveys a partly erroneous idea of the dental characters of the extinct genus so designated, the second element—*saurus*—is still more objectionable, as being indicative of a wrong affinity; since the genus belongs, not to the *Saurian*, but to the Batrachian order of reptiles. The skull, for example, is joined to the atlas by two condyles developed from the lateral occipitals, and the bony palate is formed chiefly by a divided vomer, supporting teeth.

Conceiving these objections to be valid for the rejection of the name proposed by the respected Palæontologist of Stuttgard, to whose assiduous researches our knowledge of the present most extraordinary Batrachian genus is due*, and believing that I have discovered the true and peculiarly distinctive dental characters of the reptilian genus in question, I propose to designate it by the term *Labyrinthodon*.

With respect to this very characteristic fossil of the German Keuper sandstone, it is to be regretted that, with the exception of *the teeth*, and a fragment of the skull determining its Batrachian character, only a few broken vertebræ have hitherto been found in the Continental formations; certainly nothing approaching to an entire skeleton.

On the other hand, the reptilian remains in the Warwick sandstone are still more scanty; a few teeth, or fragments of teeth, are the only fossils from which I have as yet been able to decide upon the presence of the existence of reptilian vertebrated animals in that secondary formation. Hitherto no portion of the cranium corresponding with that which yields the Batrachian character of the *Salamandroïdes* of the German Keuper has been found, and the teeth, therefore, are the only fossils on which any comparison likely to solve the question of identity or other-

* Ueber die fossilen Reptilien, welche in Würtemberg aufgefunden worden sind. 4to. 1828, pp. 35, 38, tab. 4 & 5.

wise, between the Warwick sandstone reptiles and those of the German Keuper, can be founded.

It happens, however, that the teeth of the so-called *Mastodonsaurus* or *Salamandroïdes* are of a very common and simple form; they are far from possessing those well-marked external characters that enable the anatomist to distinguish at a glance the teeth of the *Iguanodon* or *Megalosaurus*.

Of the teeth which have been discovered in the Warwick sandstone, the specimen figured in the memoir of Messrs. Murchison and Strickland (Trans. Geol. Soc. vol. v. Pl. XXVIII. fig. 8.), and which has been transmitted to me for examination, together with other fossil teeth, by Dr. Lloyd of Leamington, most nearly resembles the teeth of the *Mastodonsaurus*, in its conical figure and longitudinal striation; but as these are the commonest characters of reptilian teeth, no weight could be attached to them as proving a specific or generic identity, bearing upon a geological problem of so much difficulty as the one which attaches itself to the Warwickshire sandstones.

There only remained, therefore, to resort to the test of the intimate structure of the teeth in question; and by the kindness of Professors Jaeger and Plieninger of Stuttgard, I have been favoured with some portions of the teeth of the *Mastodonsaurus Jægeri*, from which have been prepared the requisite sections for microscopical examination.

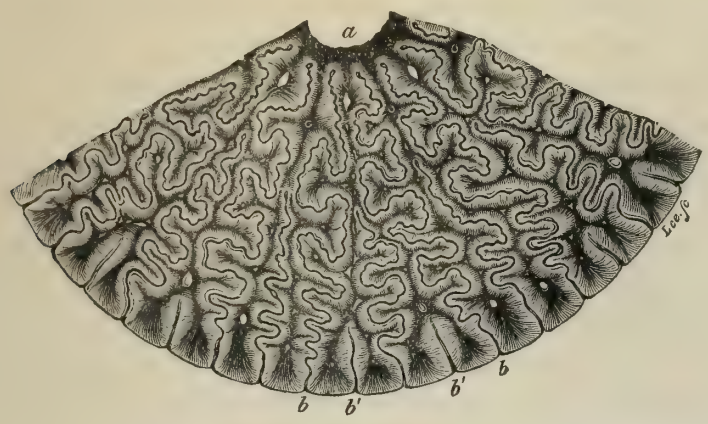
A close similarity prevails in the intimate texture of the teeth of the Crocodile, Plesiosaur, Megalosaur, Monitor, and most recent Lacertians, in which the *dentine*, or body of the tooth, consists entirely of the finest calcigerous tubes, radiating, according to the usual law, from the pulp-cavity at right angles to the external surface of the tooth, which is covered by a simple investment of enamel; and from the prevalence in the Saurian order of this, the ordinary structure of simple conical teeth, I did not build any very strong hopes of detecting such modifications of dental structure in the similarly shaped teeth of the so-called *Mastodonsaurus*, and of the reptile from the Warwick sandstone, as would be sufficiently marked and obvious to convince those who might not be familiar with the value of such characters, of their specific or even generic identity; but from this fear I have been agreeably and unexpectedly relieved.

The first transparent transverse section of the tooth of the *Mastodonsaurus Jægeri* which was placed under the microscope, and viewed by transmitted light with a low magnifying power, presented the singularly complicated structure exhibited in the subjoined woodcut; which structure, the anatomist conversant with the known modifications of dental structure in the animal kingdom, may well conceive not to have been contemplated without much surprise.

It was not, indeed, until I had caused sections of the portions of the tooth of this

species of *Mastodonsaurus* or *Labyrinthodon* to be made in various directions, and had studied them intently at several successive examinations,—comparing the appearances they presented with those of numerous examples of the teeth of true Saurians, Batrachians, and other animals,—that I at length comprehended the nature and principle of the singular cerebriform convolutions or labyrinthic gyrations which pervade every portion of the tooth of this most remarkable reptile of the Keuper formation.

Fig. 1.



Part of a transverse slice of the tooth of *Labyrinthodon Jægeri*, as seen by transmitted light; magnified 10 diameters.

A transverse section from the base of the tooth of the *Ichthyosaurus* gave the first clue to the structure of that of the *Labyrinthodon*. Before investigating the latter, I had been accustomed to regard the tooth of the *Ichthyosaurus* as presenting at its base the most complicated condition of dental structure in the class of Reptiles; but it is simple as compared with the structure which pervades nearly the entire tooth of the *Labyrinthodon*.

It is scarcely necessary to observe, that teeth vary in structure according to the number and disposition of the substances which enter into their composition.

In the herbivorous Mammalia, as the elephant, rhinoceros, horse, &c., where the crown of the tooth consists of dentine or tooth-bone, enamel, and cement, vertical folds of the enamel and cement penetrate the body of the tooth, and receive in their interspaces corresponding vertical processes of the dentine: the consequence of this disposition in maintaining a grinding surface of the tooth, by the unequal attrition of the edges of the interblended laminæ of the three different substances, is well known.

The pattern, however, in which the folds of enamel and cement are arranged in the substance of the tooth in these and other herbivorous Mammalia, although

constant in and characteristic of each genus or species, is always more or less irregular and unsymmetrical in itself.

There is no instance in the Mammalian class of these folds converging at regular intervals from the whole of the circumference of the tooth towards its centre; such a disposition of the external substance of the tooth may be traced at the base of the tooth in a few fishes, but in reptiles has hitherto been met with in the fang of the *Ichthyosaurus* alone.

In this extinct Saurian the external layer of cement (for the enamel ceases at the base of the crown) is inflected at pretty regular distances around the circumference of the tooth towards its centre, the vertical folds being straight and plane, and extending into the substance of the tooth to a distance about equal to the breadth of their interspaces. These interspaces are occupied by corresponding processes of the dentine, which radiate or diverge from the central mass of that substance.

If we could suppose the tooth of the *Ichthyosaurus* to be worn down in the living animal as far as its complicated basis, then an eighth part of the diameter of the tooth around its circumference would present a series of ridges of the denser substance converging in straight lines from that circumference towards the central pulp-cavity.

The plan and principle of the structure of the tooth of the *Labyrinthodon* are the same as those of the tooth of the *Ichthyosaurus*, but it is carried out to the highest degree of complication. The converging folds of the external cement, (Cut 1, *b*, *b*.) instead of being arrested at one-fourth of the distance from the circumference to the centre of the tooth, are continued close to that centre; and instead of consisting of simple, straight, and plane lamellæ, they are bent upon themselves in a series of irregular folds resembling the labyrinthine convolutions of the surface of the brain.

The ordinary laws of the complication of dental structure are here, however, strictly adhered to, and every space intercepted by a convolution of the converging folds of the cement is occupied by a corresponding process of the diverging layers of the dentine, and thus is produced the singularly complicated appearance which a transverse section of the tooth of the *Labyrinthodon* exhibits.

The external longitudinal flutings of the base of the tooth of the *Ichthyosaurus* are much coarser, and more indicative of the converging vertical folds of the cement than are the corresponding longitudinal lines on the exterior of the tooth of the *Labyrinthodon*,—a difference which is owing to the layer of the inflected cement being much thicker in the *Ichthyosaurus*.

The external striæ of the *Labyrinthodon's* tooth are thus of a nature to attract but little attention, and could not have been suspected to be the lines of inflection

of a series of vertical folds of the external substance, so extensive and so complicated as they actually are.

Accordingly, Professor Jaeger has described the tooth of his *Mastodonsaurus* as being simply longitudinally striated on the superficies, noting where the striæ terminate, their relative distances, and where they are most marked: the texture of the tooth where it was exposed by fracture, he states, as indeed it appears to the naked eye, to be an uniform or homogeneous compact mass (gleichformig derbe masse), and he concludes his description by stating that the tooth resembles most closely that of the *Lacerta Nilotica* and of some species of *Monitor**.

I may observe, however, that the teeth of those species of *Lacerta*, *Monitor*, and other Lacertian genera which I have submitted to microscopic investigation, have all presented the general structure of simple saurian teeth; and that, since ascertaining the structure of the *Labyrinthodon's* tooth, I have minutely inspected the outer surface of the teeth of numerous species of Saurians, but have not detected striæ penetrating the substance of the tooth, like those which indicate the complicated structure of the tooth of the Keuper Batrachian.

The portion of the tusk of the *Labyrinthodon Jægeri*, from which the microscopic sections now described were prepared, included about the middle third part of a tooth, nearly as large as the one figured by Professor Jaeger†. That tooth is three and a half inches in length, one and a half inch in breadth at the basis, whence it gradually converges with a slight bend towards the apex, which is obtuse, with a slightly depressed summit three lines in diameter, and having a small rising in the centre of the terminal depression.

The external longitudinal striæ are regularly arranged, with intervals of about one line at the base of the tooth, and they maintain nearly the same position throughout the lower three-fourths of the tooth, by decreasing in number as the tooth diminishes in thickness; they finally altogether disappear about half an inch from the summit of the tooth. Here therefore, I presume, the structure of the tooth may be more simple; but whether there be any inflected folds, or to what extent they are continued into the summit of the tooth; and whether, beside a layer of cement, the tooth be at this part invested likewise by a coating of enamel, can only be determined by the examination of sections similar to those which I have had prepared from the middle part of the crown in the tooth of the *Labyrinthodon Jægeri*.

At this part the dentine or body of the tooth is invested by only a very thin sheath of cement, and it is a vertical fold or duplicature of this cement which penetrates into the substance of the tooth at each of the striæ, which, as before

* *loc. cit.* p. 36.

† *loc. cit.* tab. 4, fig. 4.

observed, are arranged at intervals of about one line around the whole circumference of the tooth. The inflected fold runs straight towards the centre of the tooth for about half a line, and then becomes wavy, the undulations rapidly increasing in breadth; the first two, three, or four undulations are simple, then their contour itself becomes broken by smaller or secondary undulations, and these become more numerous as the fold approaches the centre of the tooth, near which it slightly increases in thickness, and finally terminates by a dilated loop or extremity (as seen in the transverse section) close to the pulp-cavity, from which the free margin of the inflected fold of cement is separated by an extremely thin layer of dentine. The number of the inflected converging folds of dentine is about fifty at the middle of the crown of the tooth, but it must be greater at the base.

All the inflected folds of cement at the base of the tooth have probably the disposition and extent above described, but as they approach their termination towards the upper part of the tooth (and we have seen that they progressively decrease in number as the tooth diminishes in size) they also gradually diminish in breadth, and consequently penetrate a less distance into the substance of the tooth.

Hence, in such a section as I have delineated, we observe that some of the convoluted folds, or those marked *b*, *b* (fig. 1, p. 506.), extend to near the centre of the tooth. Others reach only about half-way to the centre; and those folds (*b′*, *b′*), which, to use a geological expression, are "thinning out," penetrate to a very short distance into the dentine, and resemble in their extent and simplicity the converging folds of cement in the fang of the tooth of the *Ichthyosaurus*.

The disposition of the dentine in the tooth of the *Labyrinthodon* is still more complicated than that of the cæmentum. The dentine, or the main constituent of the tooth, consists of a slender central conical column, or 'modiolus,' hollow for a certain distance from its base, and radiating outwards from its circumference a series of vertical plates, which divide into two, or dichotomize once or twice before they terminate at the periphery of the tooth.

Each of these diverging and dichotomizing vertical plates gives off throughout its course narrower vertical plates, which stand at right angles or nearly so to the main plate; they are generally opposite, but sometimes alternate. Many of the secondary plates which are given off near the centre of the tooth also divide into two before they terminate: their contour is seen in the transverse section to partake of all the undulations which have been described as characterizing the inflected folds of cement which invest the dentinal lamellæ and separate them from each other.

The central pulp-cavity (Cut 1, *a*, p. 506.) is reduced to a mere line about the upper third of the tooth, but fissures radiate from it corresponding in number with the radiating plates of the dentine. One of these fissures is continued along the middle of each plate, dividing where this divides, and extending along the middle of each

bifurcation and process. The main radiating fissures extend to within a line or half a line of the periphery of the tooth, and suddenly dilate at their terminations into canals, the areas of which in transverse section are subcircular, oval, or pyriform; the branches of the radiating fissures, which are continued into the lateral secondary plates or processes of the dentinal lamellæ, likewise dilate into similar and generally smaller spaces. All these spaces or canals in the living tooth, must have been occupied by corresponding processes of the vascular pulp; they constitute as many centres of radiation of the fine calcigerous tubes, which, with their uniting clear substance, constitute the dentine.

If the dilated spaces of the complicated and ramified pulp-cavity of the *Labyrinthodon's* tooth were isolated, and their respective systems of calcigerous tubes circumscribed by a coat of cæmentum, then the tooth of the *Labyrinthodon* would present the type of that of the *Orycteropus*, and of the *Myliobates*, *Pristis*, and many other cartilaginous fishes: or on the other hand, if the pulp-cavities of the component cylindrical denticles of the tooth of the *Orycteropus* were connected together by lines converging to and uniting in a common centre, then it would somewhat resemble the peculiar type of dental structure presented by the *Labyrinthodon*.

It would be foreign to my present purpose to pursue the description of the tooth of the *Labyrinthodon* into the modifications of the dentinal tissue, as displayed by the higher powers of the microscope; suffice it to say, that the dentine everywhere presents the structure of fine calcigerous tubes, obeying in their course the usual law, *i.e.* radiating or converging, with primary curvatures and secondary undulations at right angles, or nearly so, to the surface of the dentine which the cement invests.

The number of these calcigerous tubes, which are themselves the centres of minor ramifications, defies all calculation; their diameter is $\frac{1}{7000}$th of a line, with interspaces equal to seven diameters of their cavities*.

It has already been stated, that among the few teeth presumed to be reptilian from the Warwick sandstone, the small, conical, externally striated one, figured in the memoir of Messrs. Murchison and Strickland (Geol. Trans. vol. v. Pl. XXVIII. fig. 8.), bears the nearest resemblance to the teeth of the German *Labyrinthodon* or *Mastodonsaurus*; it is however much smaller, and the cone is broader and shorter.

I have subsequently received a larger tooth from my friend Dr. Lloyd, which was discovered in the Warwick sandstone at the Coton-end Quarry. This tooth still more closely resembles in size and form the teeth of the *Labyrinthodon* figured by Professor Jaeger, especially the smaller specimens (figs. 5. and 6. Pl. IV. of his above-cited work); it differs only in being somewhat more compressed at the

* Their general disposition is shown in a section of one of the simple lateral processes of the radiating plates of dentine, in Plate LXIV. A. fig. 2. of my 'Odontography.' The undulation and ramification of the terminations of two of the calcigerous tubes, magnified 650 diameters, are figured at Plate LXIV. A. fig. 3.

base and less obtuse at the apex, resembling more the ordinary simple form of a laniary tooth. The external surface of the Warwick sandstone tooth is similarly impressed with fine longitudinal striæ, continued with a very slight degree of convergence towards the apex of the tooth, where the longest striæ terminate.

The interspaces of the striæ are more prominent and convex than in the *Labyrinthodon Jægeri.* The apex of the tooth, though rather obtuse, and worn by attrition obliquely down one side, does not present the depression and central eminence which Professor Jaeger describes as the chief characteristic of the larger tooth of his salamandroid *Labyrinthodon.* This appearance in the tooth of that species may, however, be due to the mode in which it has been worn down; and we have just seen that the tooth of the *Labyrinthodon* possesses a distinctive character of a very different and much more important kind.

It was in relation to this structural modification that I felt most anxious to examine the teeth from the Warwick sandstone. I could perceive indications at the fractured basis of the larger tooth of fissures leading from the external striæ into the substance of the tooth, and the question was, were these fissures continued to the same extent, and in the same convoluted course which they had presented in the tooth of the *Labyrinthodon* of the German Keuper? This I was unable to determine by inspection of the fractured surfaces of the dense and opake tooth from the Warwick sandstone, either by unaided vision or the use of the microscope with reflected light.

I solicited, therefore, and obtained permission from Dr. Lloyd, to have the requisite sections made, selecting such a portion of the larger tooth as least interfered with the exposition of its external form and characters.

Fig. 2.

The subjoined cut (fig. 2.) faithfully exhibits the appearance which a portion of one of the transverse sections presented, as seen by transmitted light; the complication of the structure of the tooth is as great and its plan is the same as in the *Labyrinthodon Jægeri*; all the peculiarities indeed of this most extraordinary type of tooth are so clearly preserved in the specimens from the Warwick sandstone, that I conclude it to have belonged to a reptile of the same genus as that which characterises the Keuper of Wirtemberg.

The differences which remain to be noticed in the tooth of the Warwick *Labyrinthodon* are of a comparatively slight and probably only of a specific nature.

At the upper part of the tooth a thin layer of enamel*, besides a coating of cement, is inflected at

* I have subsequently ascertained that this is not true enamel.

each groove towards the centre of the dentine, but about the middle of the tooth the enamel disappears, and the convolutions consist of interblended layers of cement and dentine. Thus, on the supposition that the tooth of the *Labyrinthodon* of the German Keuper be capped with enamel, this constituent of the tooth must have a less extent than in the congeneric tooth from the Warwick sandstone.

The inflected folds in the Warwick tooth are continued for a greater relative extent before the lateral inflections commence, than in the German species, and the inflections or anfractuosities are rather fewer in number; some of the inflected converging folds in the Warwick tooth, having nearly reached the central pulp-cavity, are reflected backwards for a short distance before they terminate.

The modifications of the complex diverging plates of the dentine correspond with those of the tooth of the *Labyrinthodon Jægeri*, the observable differences hardly amounting to anything beyond those of a specific character. Thus the peripheral or terminal quadrilateral lobes, as seen in the transverse section, are relatively longer in the *Labyrinthodon laniarius*, as the Warwickshire species may be provisionally termed.

The number of the inflected folds of enamel at the upper third of the tooth is about forty-five; such of the folds as nearly reach in the vertical direction to the apex of the tooth extend inwards transversely almost to its centre, and the shorter folds are inflected to an extent proportionate to their length.

The dentine is composed of calcigerous tubes of the same relative size and disposition as the *Labyrinthodon Jægeri*. The base of the tooth is similarly anchylosed to the osseous substance of the jaw.

In the transverse section of the smaller and relatively broader and shorter conical tooth from the Warwick sandstone already mentioned, I found, as I had anticipated, that the superficial longitudinal striæ indicated inflections of converging folds of the external cement as extensive as those in the *Labyrinthodon Jægeri* and *Labyrinthodon laniarius*. They present the same peculiar pattern, being bent from side to side in lateral undulations; but these are more complicated with numerous secondary and tertiary foldings; I find also that the second and third lateral folds, counting inwards, are the broadest, and that the rest decrease as they approach the centre of the tooth.

The section was taken from the middle of the portion of the tooth preserved; this part is not covered by enamel but by cement only, which is relatively thicker than in the *Labyrinthodon Salamandroïdes*. These differences are sufficiently characteristic of the tooth itself, but whether they indicate a difference of species or of age, or of situation in the jaws of one and the same individual, I cannot at present determine. It may be convenient, however, provisionally to indicate this tooth as belonging to the *Labyrinthodon ventricosus*.

It is my intention to prosecute further inquiries into the structure of other teeth

from the Warwick sandstones; but so far as I have hitherto had opportunities of carrying on this investigation, the results, I trust, will be allowed to be decisive as to the existence of reptiles in that formation which belong to the same natural genus, as does one of the most peculiar and characteristic reptiles of the German Keuper.

So far, therefore, as the geological problem to which reference was made at the beginning of the present paper, depends upon the determination of the correspondence, in a peculiarly characteristic dental character, of the reptilian fossils of the formations in question, the present researches must be regarded as decisive in favour of the view entertained by Dr. Buckland of the identity of the Warwick and Bromsgrove sandstones with the German Keuper. And if, on the one hand, geology has thus really derived any essential aid from minute anatomy, on the other hand I may venture to affirm, that in no instance has the comparative anatomist been more indebted to geology than for the fossils which have revealed the most singular and complicated modification of dental structure hitherto known; and of which not the slightest conception had been gained from investigation of the teeth of existing animals.

XXXII.—*Description of parts of the Skeleton and Teeth of five species of the Genus* Labyrinthodon (Lab. leptognathus, Lab. pachygnathus, *and* Lab. ventricosus, *from the Coton-end and Cubbington Quarries of the Lower Warwick Sandstone*; Lab. Jægeri, *from Guy's Cliff, Warwick; and* Lab. scutulatus, *from Leamington); with remarks on the probable identity of the* Cheirotherium *with this genus of extinct Batrachians.*

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[Read February 24, 1841.]

PLATES XLIII. to XLVII.

AT a preceding meeting I communicated the results of a microscopic examination of the teeth of the so-called *Mastodonsaurus Jægeri* of the German Keuper, and of the similarly-formed teeth of a reptile from the New Red Sandstone of Warwick, by which it was shown that they differed only in a slight or specific modification of a very peculiar generic structure, which distinguishes them from the teeth of all other reptiles, and apparently from those of all other animals; and as the terms *Salamandroïdes* and *Mastodonsaurus* were objectionable, I proposed that of *Labyrinthodon*, as expressive of this peculiar dental structure, for the genus of reptiles thus characterizing the British and Continental New Red Sandstones.

There remained then, as a subject of interesting research, to determine from the fossils of the British strata referable to the genus *Labyrinthodon*, whether these would be confirmatory or subversive of its Batrachian nature, and whether, if essentially a Batrachian, its remains would manifest any or how great an affinity to the Saurian or any other order of cold-blooded animals. The means of contributing some facts towards the solution of these questions have been obligingly afforded me by Dr. Lloyd of Leamington since the transmission of my former paper to the Society.

Having communicated to Dr. Lloyd the results of the microscopic examination

of the tooth of the *Labyrinthodon laniarius* from the Coton-end quarry, he was so good as to bring up to London the whole of the collection of reptilian fossils from the New Red Sandstone formation of Warwick and Leamington, which are deposited in the museums of those towns, and obtained for me the same liberal permission as on the former occasion, to apply to any of the teeth which these fossils might contain the microscopic test.

Amongst these fossils, two distinct species of the genus *Labyrinthodon* were at once evident, and were represented by portions of upper and lower jaws, an anterior frontal bone, two vertebræ, one of which is nearly entire, a sternum, a fractured humerus, an iliac bone with a great part of the acetabulum, the head of the femur, and two ungueal phalanges. The maxillary fragments containing teeth, besides the agreement in dental structure, as I have ascertained by microscopic examination of sections from each fossil, likewise correspond with the German *Labyrinthodon* in the relative size, mode of implantation, and arrangement of the teeth: the maxillary teeth, *e. g.*, are almost all of moderate and equal size, and these are closely arranged in a single straight row, each tooth being implanted by a broad base in a distinct but not deep socket; whilst the remaining teeth, two or three in number on each side of the upper and lower jaws, are of much larger size, and are situated less regularly at the anterior part of the dental series.

Labyrinthodon Leptognathus.

I shall commence with the description of the fossils from the Coton-end sandstone quarries, near Warwick, which indicate the smaller species of *Labyrinthodon*, to which the name of *leptognathus* is here given, in reference to the slender character of its long lower jaw.

Upper Jaw.—The first of these fossils (Pl. XLIII. fig. 1, 2, 3.) is the anterior part of the left side of the upper jaw, including the nasal bones. It shows that the maxillary or facial division of the skull was broad, much depressed, and flattened, resembling the skull of the gigantic Salamander, and also that of the Alligator, and having the outer surface of the bones strongly sculptured by depressions and furrows as in the Crocodilian family. The portion of jaw here described contains the alveoli of the anterior moiety of the single row of small teeth and the base of one of the great anterior tusks, which ranges in the same line with the small serial teeth, but is directed obliquely backwards, the smaller serial teeth projecting more vertically from the alveolar margin of the jaw, and being slightly inclined outwards. In a few places the contiguous teeth are in place, but throughout the greater part of the series only those of alternate sockets. The base of the tooth projects directly from the outer wall of the socket, there being no alveolar ridge external to it. The alveolar series in this specimen contains in an extent of two inches three lines, thirty-one sockets including the large anterior tooth. The base of the smaller tooth is subcompressed

antero-posteriorly. The large anterior tooth (Pl. XLIII. fig. 2, *a*) is three times the size of the first of the serial teeth which succeeds it, and the size of the serial teeth gradually diminishes as they are placed further back, so that the eighth tooth, counting the sockets from the first, is little more than half a line in diameter at its base; beyond this the teeth are of equal size, slender in proportion to their length, and gradually diminishing from the middle of the crown to the apex, which is not very acute where entire; a linear pulp cavity is continued along the centre of the tooth, nearly to this part. The transverse section of the apical two-thirds of the tooth is cylindrical, its outer surface smooth; the basal third is fluted, as in the teeth of the lower jaw; the outer wall of the socket is anchylosed to this fluted base, and slightly excavated in the interspaces of the teeth that are in place. From the flatness and thinness of the maxillary bones the sockets of the teeth are necessarily shallow. The length of the common-sized serial teeth is about two lines, their greatest diameter one-third of a line; the diameter of the base of the large internal anterior tusk is two lines and a half.

The outer surface of the maxillary bone begins to bend from the perpendicular almost immediately above the alveolar process, and is continued through the rest of its extent in a nearly horizontal plane. The whole breadth of the left upper jaw appears to be included in the fossil for the antero-posterior extent of an inch opposite the middle of the dental series. The breadth of this part from the median longitudinal suture to the external alveolar process is one inch three lines; two inches and a half is therefore the breadth of the skull at this part. The upper jaw gradually expands to the posterior part of the fragment, where it is one inch and a half in breadth on the left side; the anterior part of the fragment, which contains the large tusks, slightly expands or inclines outwards. Where the upper jaw is entire, a portion next the median suture, four lines in breadth, is separated from the maxillary bone by a longitudinal harmonia running nearly parallel with the median one; the bone so defined corresponds with the position of the nasal bone in the Crocodile. The whole of the outer surface of the bones here described is sculptured with large irregular grooves and sinuses. One of the largest grooves, which is an angular and not a rounded furrow, runs nearly parallel with the alveolar process, between two and three lines above it, defining it, as it were, from the upper and flat surface of the jaw; a second principal furrow, as wide but less angular than the outer one, commencing at the posterior part of the fragment, a line and a half distant from the outer one, inclines inwards as it advances forwards with a slightly irregular course, and terminates in the fragment preserved at the naso-maxillary suture. The above two principal grooves are separated by a longitudinal row of elliptical pits, which increase in size as the grooves diverge, and the wider anterior interspace is occupied by additional smaller pits. The portion of the upper maxillary bone included between the oblique groove and the nasal suture is marked with

longitudinal impressions or smaller grooves, which converge anteriorly. The upper surface of the nasal bone is impressed by elliptical and oblong pits, the intervening ridges of which form an irregular open network. The preceding sculpturing of the nasal and maxillary bones resembles that of the corresponding bones in the Crocodiles, but presents a relatively larger and coarser pattern; and when it is remembered that analogous sculpturing characterizes the crania and other bones of certain species of fishes, the ribs and sternum of the *Trionyx* and the jugal bones of the Spotted Cavy among Mammalia, much importance need not be attached to this indication of the Saurian affinities of the present extinct reptiles.

The affinity of the *Labyrinthodon* to the Crocodile is more essentially shown by the broad and entire upper jaw, which deviates widely from the Batrachian condition of the same part.

In both the caducibranchiate and perennibranchiate species the upper maxillary bones present the form of slender elongated styles, attached only by a slightly expanded anterior extremity, from which they project backwards and generally terminate in a free and disengaged point: the external surface rises nearly vertically above the alveolar margin, and is not extended horizontally over the upper surface of the skull, but a very wide interval is left between the maxillary and nasal bones; and while the maxillary bones thus form so small a proportion of the upper wall of the nasal cavity, their palatal processes contribute as little to the formation of the floor of the same cavity. In the Crocodiles, on the contrary, the palatal processes of the maxillary bones extend horizontally inwards and meet at the middle line of the roof of the mouth, and thus form an unbroken floor to the nasal cavity. In the present fossil we have already seen that the superior maxillary extends inwards to the nasal bone, forming with it a continuous strong bony roof over the nasal cavities. The whole of the under surface of the fossil was covered with the sandstone matrix, but the fractured margin, opposite the alveolar border, exhibited the edge of a thin plate of bone, uninterrupted in the longitudinal extent, and forming the floor of a wide and shallow nasal cavity; thus affording a strong indication that the Labyrinthodon breathed air like the higher reptiles. That the bony palate extended as far in the transverse as in the longitudinal extent was indicated by the projecting base of a fractured conical tooth, twice the size of the large anterior fang of the maxillary series, and situated internal to the anterior small serial teeth. Although the *Labyrinthodon* resembles the Crocodile in the character of the bones forming the upper surface of the maxillary part of the cranium, and in the interception of a wide and shallow nasal cavity between two horizontal plates of bone, yet the main evidence of its affinity to the higher Saurian was to be derived from the condition of the bony palate, first in regard to the bones composing it, and, secondly in their relation to the dental system.

In Crocodiles, the floor of the nasal cavity is chiefly formed by the maxillary

bones; in Batrachia, by the palatines and vomer: in all Crocodiles the bones of the palate are edentulous, in all Batrachia they support teeth. There was evidence in the fossil in question of a large laniary tooth projecting from the palatal surface of the mouth, internal to the series of maxillary teeth. I had first to determine whether this was supported, like the great laniary teeth of the lower jaw, upon the same bone, viz. the superior maxillary, which supported the serial teeth, or whether it was a true palatal tooth. I am indebted to the skilful sculpturing of Mr. Scharf, spontaneously undertaken by him with a view to render his drawings of the present fossil more clear and instructive, for the means of determining this question, and for bringing into view some most interesting parts of the cranial anatomy of the *Labyrinthodon.* The palatal processes of the maxillary bones, instead of extending to the middle line, as in the Crocodiles, are very narrow, as in the Batrachia. The osseous roof of the mouth is principally constituted by a pair of broad and flat bones (Pl. XLIII. fig. 2, *b*), analogous to those which Cuvier describes as a divided vomer in the Batrachia. These bones are, however, of much greater relative extent than in any known Batrachia; they defend the mouth with a more extensive roof of bone than exists in any lacertine reptile; physiologically the *Labyrinthodon* in this part of its structure comes nearest to the Crocodile, but the structure itself, morphologically, is essentially Batrachian; that is to say, the bony roof of the mouth is formed by a greater development of the vomerine bones, situated, as in the Batrachians, at a part of the skull which is occupied solely by the maxillary bones in the Crocodiles.

The vomerine bones vary much in their form in the Batrachia; those of the Menopome come nearest in this respect to the *Labyrinthodon*, especially in the expanded anterior extremity of the bone, and it is upon the outer side of this expansion that the large tooth just alluded to is situated in the present species of *Labyrinthodon.* The corresponding part of the palatal bone in the Menopome and gigantic Salamander supports a transverse row of small teeth; and the large tooth of the *Labyrinthodon* is the outermost of a similar transverse row of teeth extending, five in number, across the anterior expansion of each palatine bone, the three median ones being small and equal, the two outermost much larger. In the present fossil these teeth appear to be alternately shed and reproduced; that is, the first, third and fifth, counting outwards from the middle line, were in place, the second and fourth being indicated by their empty sockets: this is analogous to the condition of the maxillary series of teeth, and it is an order of shedding and renewal which is common in many fishes where these processes succeed each other frequently and quickly, and by which the dental series is always kept in an efficient state. The outermost or fifth tooth is placed behind, as well as to the outer side of the socket of the fourth displaced tooth; and, while it terminates the trans-

verse row of palatal teeth, it forms the commencement of a longitudinal row of small and equal-sized teeth, which is continued backward from the large exterior tooth of the transverse row along the outer margin of the vomerine bone: the whole of the series of palatal teeth thus describe an arch nearly concentric and parallel with the external maxillary series of teeth, and the large tusks occupy the corresponding situations in each row. In the lacertian reptiles the examples of such an inner or palatal row of teeth are very few, and the series, when it does exist, is very short, and is situated towards the back of the palate upon the pterygoid bones, as in the *Iguana* and *Mosasaur*. With the Ophidians the comparison of the present reptile is out of the question; and their palatine teeth are never arranged transversely to the axis of the mouth. In the Batrachians this is the most common disposition of the palatal teeth; they form a short transverse series at the anterior part of the divided vomer in the Frog, and at the posterior part of the divided vomer in certain Toads, as *Hyladactylus*; the palatal teeth form an extensive transverse row along the anterior margin of the vomer in the *Menopome* and gigantic Salamander, but are not extended longitudinally. In the *Amphiume*, on the contrary, the palatal teeth form a nearly longitudinal series along each outer margin of the long and narrow vomerine bone: the extinct *Labyrinthodon* combines both these dispositions of the palatal teeth. In the Menopome and most other Batrachians the posterior extremities of the maxillary bones are free, and the wide posterior palatal spaces, which are covered by membrane only in the recent animal, are uninclosed externally. In the genus *Rana* the pterygoid bones extend outwards and forwards so as to touch the palatine and maxillary bones, and circumscribe this aperture, which, however, is of great extent. In the *Labyrinthodon* the aperture (Pl. XLIII. fig. 2, *c*) is much more completely circumscribed by bone, and, from the greater development of the vomerine bones, its extent is much diminished. In the present specimen the posterior palatal aperture forms a longitudinal ellipse, ten lines in the long and five lines in the short or transverse diameter: it occupies apparently the same relative position as in the *Iguana*, but a much smaller proportion, if any, of its posterior contour must be completed by the pterygoid bone in the *Labyrinthodon*. The anterior transversely produced plate of the vomerine bone has its external margin expanded in the longitudinal direction, and abuts by an extensive slightly convex surface against the narrow palatal process of the upper maxillary bone. The anterior and posterior margins of this process of the vomerine bone are concave, the former (Pl. XLIII. fig. 2, *d*) being the posterior boundary of the anterior palatal opening, and the latter the anterior boundary of the posterior palatal opening. What the extent of the anterior palatal orifice may have been, and how far the superior maxillary and intermaxillary bones extended beyond the part of the upper jaw at which the present fossil terminates, is indicated by the length of the lower jaw of

the same species next to be described, and by the fragment of the upper jaw of the second and larger species of *Labyrinthodon.* The broad palatal plate of the palatine bones in the present fossil extends two inches behind the transverse row of teeth, and probably much further in the entire skull; it is nine lines in breadth anteriorly and six lines in breadth on the inside of the posterior palatal foramen; the surface next the mouth, which does not support teeth, is smooth and slightly convex. From the curve of the remaining part of the contour of the anterior palatal foramen (*d*, fig. 2. Pl. XLIII.), it may be concluded that it was not confluent with its fellow, as in the Crocodiles, or as in the Frog and Menopome, but that the two were distinct as in the *Iguana.* From the structure of the portion of the nasal cavity preserved in the present fossil, it may be inferred that the *Labyrinthodon* differed from the Batrachians, and resembled the Saurians in having distinct posterior nasal apertures surrounded by bone, and that its mode of inspiring air was the same as in the higher organized reptiles; other physiological inductions consequent upon this will be noticed in the description of the portion of skull of the larger species of *Labyrinthodon*; and I shall conclude the description of the present fossil by again calling attention to the satisfactory proof of its essentially Batrachian affinities, which the structure of the palate and palatal teeth have yielded.

Lower Jaw.—The next fossil which I proceed to describe, and which, like the preceding one, is from the sandstone in the neighbourhood of Warwick, consists of six inches of the anterior part of the left ramus of the lower jaw (Pl. XLIV. figg. 8 and 9); this ramus is slender, straight, and with its symphysial extremity abruptly bent inwards; the inner line of the symphysis here forming a regular and deep curve. Its breadth, at the posterior fractured part, is ten lines; at the anterior part, behind the inflected symphysis, seven lines; the breadth of the anterior fractured portion is one inch. The structure of this long and straight ramus of the jaw presents almost as striking a Batrachian character as any of those derived from the foregoing fossil; that is to say, the angular piece is of great breadth, extends on both sides of the jaw, and is continued forwards to near the symphysis, forming the whole of the inferior part of the ramus of the jaw, and extending upon the inner as far as upon the outer side of the ramus, the inner plate performing the function of the detached 'os operculare' in the Crocodile's jaw. The dentary piece is supported upon a deep and wide groove along the upper surface of the angular piece, which groove looks obliquely outwards; the angular piece also projects beyond the outer edge of the groove, so as to form a strong convex ridge on the external side of the jaw below the dentary piece; this character, which in the large Bull-frog (*Rana pipiens*) is confined to the posterior part of the maxillary ramus, is here continued to near the anterior extremity. The teeth in this fragment are long and slender, and so closely correspond in size and shape with those in the upper

jaw last described, that they must be regarded as belonging to the same species. There are not less than fifty sockets in a single linear series, and at the anterior inflected part of the jaw is the base of the socket of a large tooth six lines in diameter; the serial teeth gradually diminish in size toward the anterior portion of the jaw; the posterior teeth, which are slightly compressed at their base, in the antero-posterior direction, present here about a line and a half in diameter; the anterior ones half a line across the same part; the length of some of these small anterior teeth above the sockets is three lines, they are terminated by subacute extremities; the sockets do not lie between parallel lines; the alternate ones are placed a little more internally. The teeth were present chiefly in the more external sockets; but where they remained in both, the row of teeth presented the same slightly zigzag disposition. Owing to the circumstance of the anterior part of the jaw having been broken, it cannot be determined whether any of the smaller or serial teeth were continued external to the large anterior tusks,—a remarkable ichthyic character which I shall have to notice in a subsequent fossil. The sockets of the teeth are as shallow in the present as in the preceding fossil; the outer wall is more developed than the inner, and the anchylosed bases of the teeth more nearly resemble in their oblique position those of the existing Batrachia. The teeth are directed slightly inwards, and are probably received within the series of the upper jaw when the mouth is closed. The striation and fluting is confined to the basal third of the tooth, as is also the labyrinthic inflections of the external cement. Above this part the dentine consists of fine calcigerous tubes, radiating from the linear remains of the pulp-cavity at right angles to the surface of the tooth; being parallel with the axis of the tooth where they form its apex, and gradually inclining outwards until they become transverse to that axis, which is their disposition in the body of the tooth, between the apex and the commencement of the inflected vertical folds of the cement. Beyond this part, therefore, the tooth of the *Labyrinthodon* resembles, in the simplicity of its intimate structure, that of the entire tooth of the ordinary Batrachia and of most reptiles. The vertical inflected processes of the cement are at first short and straight, occurring at pretty regular distances around the circumference of the tooth; so that here the tooth partakes of the structure which I have before described as characterizing the base of the tooth of the *Ichthyosaurus*. Soon, however, the primitive inflected folds of cement sink deeper into the dentine and commence their undulating course; other processes, at first simple like the preceding, begin to penetrate the dentine at the interspaces of the primary folds; these begin to take on a sinuous course a little nearer the base of the tooth; and a transverse section at this part exhibits the modification of the labyrinthic structure exhibited in the woodcut, fig. 2, p. 511.

The long and slender character of the maxillary ramus, suggesting the name of

the species of *Labyrinthodon* to which it belonged, will give an idea of the proportion of the skull included in the first-described fossil; the length of the head as compared with the breadth approximates more nearly to the proportions of that of the Crocodile and *Nothosaurus* than to those of the ordinary Batrachian skulls: among existing Batrachia, the Amphiuma, in this respect, seems to have most closely resembled the present species of *Labyrinthodon.*

Vertebra.—The vertebra here described (Pl. XLV. figg. 5–8.) was discovered in the same sandstone quarry at Coton-end as the portion of the skull and upper jaw of the *Labyrinthodon leptognathus*, and it bears the same proportionate size to those parts as exists between the vertebræ and skull of the Menopome, and between a larger vertebra from the Warwick sandstone and the jaws of the larger species of *Labyrinthodon* next to be noticed. In the larger vertebra alluded to there is evidence of a condition of the articular extremities characteristic of the lower or perennibranchiate division of Batrachia among existing reptiles. From the essential resemblance which will be pointed out between the jaws of the two species of *Labyrinthodon*, it could not be anticipated that their vertebræ would present two types of structure so different as the bi-concave and concavo-convex articulations. From the figure given of the smaller vertebra now under consideration*, it appeared nevertheless that one of the articular surfaces of this vertebra was convex, and from the form of the articular processes (for this figure is unaccompanied by any detailed description), this surface seemed to be the posterior one; I therefore wrote to Dr. Lloyd, requesting permission to have the vertebra transmitted to me. It was imbedded, with the exception of the surface figured in the plate quoted, in the sandstone matrix. Part of the anterior articular surface of the body of the vertebra was uncovered, the opposite end of the vertebra was broken off, and a mass of the sandstone projected from the broken surface. With the assistance of Mr. Clift, sufficient of this matrix was cleared away to expose the centre and bottom of a concave surface (Pl. XLV. fig. 8.), to all appearance similar in depth and form with that on the anterior end of the bone (Pl. XLV. fig. 7.); thus proving its correspondence in this important character with the vertebra of the larger species of *Labyrinthodon.* The body of the vertebra is subelongate and subcompressed, with a smooth exterior surface terminating below in a slightly produced longitudinal median ridge. Its length is nine lines, its breadth at the middle four lines; at the articular extremity nearly six lines. The articular concavity appears, as in the larger vertebra, not to have begun immediately from the margin, but to have been surrounded by a flattened circular surface; this part, however, is much broken. The depth of the articular concavity is not very great; at least four lines of the osseous tissue must have intervened at the middle of the body of the vertebra between the anterior and posterior concavities; these are much deeper and more conical in the perennibran-

* Geol. Trans., Second Series, vol. v. Pl. XXVIII. fig. 10.

chiate reptiles. The smooth lateral surface of the vertebral body is not continued in a regular curve to the lower margin of the vertebra, but bends toward that ridge somewhat abruptly at two lines distance from it, as shown in figures 5. and 7. Pl. XLV. The present vertebra exhibits the same exceptional condition in the Reptilian class as do the vertebræ of existing Batrachians, in having the superior arch or neurapophyses anchylosed with the centrum. The vertebra belongs to the dorsal series, and from each side of the base of the neural arch there extends obliquely, outwards and upwards, a thick and strong transverse process, the fractured condition of which, on both sides, prevents, however, its length from being ascertained. A very slight ridge ascends from the centrum along each side of the under part of the transverse process; the two ridges slightly converging and bounding a shallow concavity beneath the transverse process. The upper part of the base of the transverse process is continued in an uninterrupted curve into the posterior oblique processes, but it is separated from the anterior ones by a deep oblique and slightly curved fissure. The anterior oblique articular surfaces commence three lines behind the articular surface of the body of the vertebra; they diverge as they pass forward, and thus leave that part of the medullary canal exposed; the aspect of the articular surface is obliquely upward and inward. The spinous process commences at their angle of union, and its base is extended to the corresponding angle of union of the posterior oblique processes, gradually increasing in thickness as it proceeds backwards; the spinous process was broken off close to its base. The posterior articular processes extend beyond the posterior articular surface of the body of the vertebra as far as the anterior articular surfaces fall short of it; and they must have covered in the succeeding vertebræ that portion of the spinal canal so left unprotected by its own arch. The spinal canal is slightly expanded at its two extremities, and appears, so far as I have been able to fairly excavate it, to sink in its progress into the substance of the centrum, approaching, as it were, to that peculiar structure which prevails in the still more ancient reptiles of the magnesian conglomerate. The strength and direction of the transverse processes indicate an expanded respiratory cavity protected by ribs.

Episternum.—A symmetrical bone, most resembling the episternum of the *Ichthyosaurus*, but with the median piece broader, flatter and thinner, so nearly corresponds in its proportions with the preceding vertebra that I here describe it, as belonging very probably to the *Labyrinthodon leptognathus* (Pl. XLV. figg. 9 and 10). The stem, or middle piece of this bone diminishes to a mere plate or film below, and thickens towards the upper end where the cross-pieces are given off, and these pass outwardly at right angles to the median stem and support, each, a pretty deep and wide groove, contracting to a point at the upper part of the median stem: these grooves indicate strongly the presence of clavicles, which are wanting in the Crocodiles, where the sternum or episternum presents only its median piece, with

broad lateral cartilages for the attachment of the coracoids. In the Lacertians it would seem that these lateral cartilages were ossified, and the sternum thus converted into a large rhomboidal plate.

In the anourous Batrachia there are clavicles as well as coracoids; and in the Toad the mesial extremities of the clavicles rest upon the transversely expanded anterior extremity of an episternal bone, which among recent reptiles bears the nearest resemblance to that of the *Labyrinthodon*, to which genus the present bone most probably belonged. It is represented of the natural size, at Plate XLV. figg. 9. and 10.

The fossils above described, consisting of a part of the skull and dental system, a dorsal vertebra, and an episternum, prove the *Labyrinthodon* to have been essentially Batrachian, with striking and peculiar affinities to the higher Saurians; these affinities lead, in the form of the skull and the sculpturing of the cranial bones, to the Crocodilian group; and in one part of the dental structure, in the form of the episternum and the biconcave vertebra, to the extinct Ichthyosaur; while in the condition of the bony palate the deviation from its essentially Batrachian character produces a resemblance to the Lacertian type.

The anchylosis of the base of the teeth to distinct and shallow sockets is a point in which the *Labyrinthodon* resembles certain fishes, as the *Sphyræna*: I am disposed also to believe, from the absence of any trace of alveoli of reserve for the successional teeth, that these were reproduced, as in many fishes, especially the higher *Chondropterygii*, which, it may be remembered, formed the *Amphibiæ natantes* of Linnæus, in the soft mucous membrane or gum which covered the alveolar margin, and subsequently became fixed to the bone by anchylosis, as in the Pike and Lophius among osseous fishes. Nor is it extraordinary that the present extinct Batrachian genus should have its relations of affinity thus radiating in different directions, since we find in the extinct reptilian forms of a later epoch, the combination of Saurian characters with Ichthyic vertebræ and extremities. We possess, as yet, no indication from fossils of the structure or form of the locomotive organs of the *Labyrinthodon leptognathus*. But it is by no means improbable that the impressions figured by Messrs. Murchison and Strickland, found on a slab of sandstone from Shrewley Common, Warwick, are the foot-marks of this very species.

The learned authors of the paper quoted, state their belief that these footsteps "were formed by an animal probably allied to the Batrachia." (*l. c.* p. 318.) They differ from the feet of Frogs in having the outer toe of both the hind- and fore-feet the longest, while in Frogs the second toe is longest: it is moreover evident that the animal possessed a tail. In both these deviations from the Batrachia a corresponding approach is made to that family of reptiles to which the modifications of the Batrachian characters of the fossils in question have tended.

Labyrinthodon pachygnathus.

Lower Jaw.—I now proceed to describe the fossils on which I have founded a second species of *Labyrinthodon*, and shall commence with a well-preserved portion of the right ramus of the lower jaw (Pl. XLIV. figs. 1, 2, 3.). This fossil measures nine inches and a half in length; the bone is thick and rounded, one inch and a half deep and one inch broad at the posterior fractured part, thirteen lines broad and seven lines deep at the anterior expanded and subdepressed end, which is curved inwards towards the symphysis of the jaw, and which supports two of the great cuspidate or laniary teeth, and the socket of a third. The structure of this lower jaw, which was broken across into two nearly equal portions, was the first object of attention. On the inner side of the anterior moiety it appeared to be strengthened by an opercular piece, in the form of a thin plate, gradually narrowing to a point, and terminating at the beginning of the inward curvature of the ramus (fig. 2.). This was obviously a more complicated structure than exists in the jaws of fishes; whilst in reptiles the inner side of the ramus of the jaw is supported by a distinct plate of bone in both Batrachians and Saurians. This complication, however, is due to a different structure in the Batrachia from that which obtains in the Sauria. In the lower jaw of the Frog, for example, it is produced by a continuation of the angular element upon the inner side, as high as upon the outer side of the jaw; whilst in Saurians the inner splint-like plate exists as a distinct piece, to which Cuvier has given the name of 'os operculare.' The question then to be determined was, to which of those structures was due the appearance above mentioned, of an opercular piece on the inner side of the maxillary ramus in the Keuper reptile? I may first observe, that the outer side of this ramus presents a structure not to be found in any Saurian jaws, viz. a well-marked longitudinal impression running parallel with the lower border of the jaw, about half-way between that and the alveolar border, towards which it gradually inclines, and then abruptly bends downwards and backwards. This impression evidently leads to a harmonia or toothless suture (like those which join together the different elements of a compound jaw), into which the sandy matrix has insinuated itself. The lower piece corresponds in depth and forward production with the large angular element of the jaw of the Frog, in which the angular piece is continued nearer to the symphysis than in any known Saurian; but in the fossil it swells out as it were beyond the level of the upper or dentary piece, and forms a bold and broad convex ridge along the lower part of the outer side of the ramus, which subsides at only a short distance from the symphysial bend. The angular piece forms a similar projection on the outer side of the posterior half of the jaw in the Frog.

Two transverse fractures of the present fossil display the relations of the external plate of the angular piece with the thin internal bony laminæ; the two pieces are

uninterruptedly confluent, and form a single broad and strong piece of bone, supporting the dentary piece upon a groove along its upper surface (fig. 2, *b.*), and terminating anteriorly at the bend of the expanded dentary element, which there receives the extremity of the angular element in a notch.

The fossil fragment exhibiting the above structure is five inches and a half in length, and probably forms little more than the anterior third of the ramus of the jaw; there is sufficient, however, to demonstrate that its structure is essentially Batrachian. A similar portion of the lower jaw of a Saurian would have exhibited either the dentary element simply, or inclosed at the posterior fractured end, between the extremities only of the separate angular and opercular elements. The continuation of the angular element alone, forming the lower half of the ramus, to near the symphysis, and supporting the dentary piece in a groove on its upper surface, is as striking a Batrachian character in the fossil of the British sandstone as that observed by Prof. Jaeger in the occipital bone of the great *Salamandroïdes* of the German Keuper.

The smaller serial teeth in the present portion of jaw are about forty in number, and their sockets are in close contact with each other; they very gradually diminish in size as they approach both ends of the series, but chiefly so towards the anterior part of the jaw. One of the smallest teeth at this end of the jaw is recumbent in front of the great laniaries; I think it very probable that it was an incompletely developed tooth of replacement, not yet erected and anchylosed to the bone,—a circumstance in accordance with the view which I have entertained of the place of development of the successional teeth. The alternate sockets are empty in a considerable portion of the posterior part of the series, agreeably with the law of shedding and replacement illustrated in the *Lab. leptognathus*, so that the teeth thus appear to be separated by wider intervals than their sockets prove them to be. The form of the teeth is conical, with the base slightly compressed in the direction of the axis of the jaw; the largest transverse diameter of one of the posterior of these serial teeth, where it emerges from the socket, is three lines; the same diameter of the anterior serial tooth is one line and a half, its length four lines and a half. The great laniary teeth appear to be three in number in each symphysis, and the one nearest the symphysis is somewhat larger than the other; but they are probably not in place and use at the same time. The greatest diameter of the base of the largest of these tusks, which is subcompressed, is five lines; its length, judging from an entire tooth of the same species, must have been at least one inch and a half. The lines of the inflected cæmentum form well-marked longitudinal striæ all around the basal half of the tooth, and the interspaces of the striæ form convex ridges, as in the large tooth of which I described the labyrinthic structure in my previous paper, and which is most probably a laniary tooth of the present species. These ridges are fewest near the termination of the striæ, being divided and multiplied by new longitudinal striæ,

caused by new inflected folds of the cement near the basis of the tooth; the apical half of the tooth has a smooth and polished external surface; the pulp-cavity is continued of small size into the centre of this part of the tooth. In the smaller serial teeth, which in other respects, except their less gradual diminution of size, correspond with the preceding description of the anterior larger tusks, the central pulp-cavity is more quickly obliterated: the texture of the teeth is dense and brittle; the alveoli, as already described, are large, moderately deep, but complete. The outer wall of the alveolar processes in the present fossil is not higher than the inner wall, as is the case in Frogs and Toads, the Salamanders and the Menopome, in all which Batrachians the base of the teeth is soldered to the inner side of an external alveolar plate, as in the Lacertians. It may be said, therefore, that in the more complete structure of the socket the *Labyrinthodon* manifests an affinity to the Crocodilian and Plesiosaurian reptiles; but, on the other hand, a similarly complete dental socket is present in certain Scomberoid and Sauroid fishes. The base of the teeth, moreover, in the *Labyrinthodon pachygnathus*, as in the *Lab. leptognathus*, is anchylosed to the bottom of the socket, as is likewise the case in the fishes cited. We have a still more striking ichthyic character in the *Labyrinthodon*, in the continuation of the row of small teeth anterior and external to the two larger teeth. For a double series of teeth, thus occasioned, does not exist in the maxillary bones, either superior or inferior, of any Saurian reptile; but in the Batrachian order it is found in the lower jaw of the *Cæcilia*, and it is not an uncommon structure in fishes. We cannot notice without interest the manifestation of another ichthyic character in the primæval Batrachia whose remains we are attempting to interpret*.

Upper Jaw.—The second fossil of the *Labyrinthodon pachygnathus* which I have to notice is a *fragment* of the superior maxillary bone of the left side (Pl. XLIII. fig. 4.), three inches and a half in length, including twenty-four of the serial teeth; these teeth resemble those of the lower jaw, being moderately short, with a thick antero-posteriorly subcompressed, finely-striated base, and a sharp, subincurved apex. The outer alveolar plate is rather deeper than the inner one, but the teeth are implanted in distinct, though wide and shallow, elliptical sockets. The labyrinthic structure is confined to the striated base: in the upper half of the crown it is as simple as in the *Ichthyosaurus* or Crocodile, but there is no true enamel: the outer coat consists of a thin layer of cement. The relation of the cement to the dentine, as exhibited by a transverse section of the tooth, one line above the socket, is well calculated, from its greater simplicity, to illustrate the principle of the more complicated modifications of the labyrinthine dental structure first discovered. The processes which radiate from the pulp-cavity, twelve in number at the line of section, proceed straight to about midway between the

* The successional teeth in *Plesiosaurus* and *Nothosaurus* are sometimes so far developed before they displace their predecessors, as to cause the appearance of a double row.

centre and the circumference of the tooth, where each terminates in a slight dilatation. In like manner, the inflected folds, converging from the circumference of the section, proceed inwards in a straight line to within one-fourth of the distance to the central pulp-cavity. The inflected substance consists of the thinnest layer of cement. The calcigerous tubes radiate according to the usual laws, and resemble in diameter, in the width of their interspaces, in their secondary undulations, their dichotomous bifurcations and small lateral branches, the same tubes in the large tusk with the more complex labyrinthine structure.

The external wall of this portion of the jaw is straight, and nearly flat; and slopes upwards and slightly inwards from the narrow ridge which runs along the outside of the alveoli. The inner or palatal process of the jaw is as narrow as that of the *Labyrinthodon leptognathus*, and terminates internally by a smooth, regularly rounded, convex margin, which describes a slight concavity in the antero-posterior direction, and most probably formed the external boundary of the posterior palatal opening: the breadth of the palatal plate of the maxillary bone at the middle of this fragment is four lines, but at each extremity of the fragment it is six lines. At the posterior part of the fragment the palatal surface is flat, and impressed with a few small pits: anteriorly it is traversed by a shallow longitudinal groove.

This condition of the palatal process of the maxillary corresponds more closely with that in the Frog than in any other existing reptile. In all the Batrachia the palatal process of the maxillary bone is very narrow, and is not extended inwards at any part to join the palatine bone, so as to complete the bony roof of the mouth; but the inner boundary of the palatal process in the Frog is more parallel with the alveolar ridge; and a portion, corresponding in extent with the present fragment, would not give that concavity of the inner border of the palatal process which the present fragment presents

I suppose, therefore, that the palatal process here must have extended inwards at the anterior part of the maxillary, and probably so as to join the palatal bone, as in the *Lab. leptognathus*, and agreeably with the traces of an extended bony floor of the nasal cavities exhibited in the portion of the upper jaw which comes next to be considered.

This characteristic fossil, which is from the quarry at Coton End, includes a considerable portion of the left maxillary and intermaxillary bone, and shows the lateral contour of the anterior palatal foramen (Pl. XLIII. figg. 9 and 10). The superior or external plate of the intermaxillary bone is broken away, but the external plate of the maxillary bone remains, together with the internal or palatal plate, in the portion of that bone which is here preserved. The outer margin of the present fossil is impressed with a portion of a wide groove, having the same sinuous contour as the long oblique groove in the fragment of the upper jaw of the smaller species of *Labyrinthodon.* The inner border of the fragment is obliquely

thinned off, apparently for supporting the corresponding margin of the nasal bone: two or three wide, deep, subangular longitudinal grooves run nearly parallel with this border, external to which other shorter and similar grooves radiate towards the outer margin of the fragment. In no species of Crocodile is the external surface of the cranial bones sculptured by such deep and wide incisions, or excavations, relatively to the size of the bones. The ridges between these grooves in the *Labyrinthodon* have their edges rounded off. The depth of these inflections of the external surface of the bone brought to mind the corresponding inflections of the external surface of the teeth which form so striking a characteristic of the present extinct Batrachian family. The interspace between the sculptured maxillary bone and the co-extensive palatine plate here preserved, is nowhere more than two lines and a half in depth; but the two plates may have been unnaturally approximated by pressure. The wide and shallow nasal cavity is occupied by the matrix (Pl. XLIII. fig. 10, *e*).

The chief deviation from the Crocodilian type of structure which the present fossil presents, is the continuation of the palatal plate (*b*) of the intermaxillary bone for some distance, about an inch, to the outer side of the base of the external plate or process.

In the Crocodiles the external wall of the intermaxillary bone rises from the outer border of the palatal process, and is united by the whole of its posterior margin with the maxillary bone. A different structure of the intermaxillary bone prevails in the Batrachia: here the external is not co-extensive with the internal or palatal plate, but it rises from a longitudinal tract traversing the middle of the palatal plate, in the form of a compressed process, leaving an interspace between its outer margin and the maxillary bone: in the Frogs there is likewise an interspace between the external plates of the two intermaxillary bones, which does not exist in the Menopome, among the perennibranchiate Batrachia. Now, in the *Labyrinthodon*, the intermaxillary bone presents the same peculiar modification of the Batrachian condition of this bone as in the higher organized Batrachia. The palatal process of the intermaxillary, for example, is extended beyond the outer plate, both externally (Pl. XLIII. fig. 9, *b*), and, but in a less degree, internally, where it forms part of the boundary of the anterior palatal foramen (fig. 9, *c*), whence the outer plate rises in the form of a compressed process from a longitudinal tract (fig. 9, *a*), on the upper part of the palatal process. The outer plate in the specimen is broken off near its origin, and the fractured surface gives the breadth of its base, stamping the fossil with a Batrachian character conspicuous above all the Saurian modifications by which the essential nature of the *Labyrinthodon* appears at first sight to be masked.

Anterior frontal. (Pl. XLIII. fig. 11.)—With the indications of Crocodilian affinities in the maxillary portion of the cranium just described, we cannot feel sur-

prised to find other bones of the cranium in the present Batrachian family modified after the same type; such appears to be the case in the fossil now under consideration, which I regard as an anterior frontal bone, similar in form to that of the Crocodile. It presents a superior, horizontal, expanded and slightly convex surface, pitted with large irregular impressions, thinning off to a fine edge at the inner side, and sending downwards from its posterior and outer part a broad and slightly concave process, the smooth surface of which strikingly contrasts with the irregularly sculptured one of the horizontal plate. This smooth surface, if I am correct in my idea of the nature of the bone, must form a part of the anterior boundary of the orbit, which it indicates to have been of large size. The posterior margin of the horizontal plate does not extend so far back, or overhang so abruptly the smooth orbital plate, as in the Crocodile.

The orbital plate is also characterized in the present fossil by a deep pit, from which a groove is continued forwards; there is a smaller foramen in the corresponding part of the smooth orbital plate in the anterior frontal of the Crocodile. The present fragment is two inches and a half in length, and the same in breadth; the depth of the orbital plate is one inch three lines; the thickness of the fractured angle of the bone, which would have joined the lachrymal, is three lines.

Hitherto I have not received any other portions of the cranium of the *Labyrinthodon pachygnathus* than those which have been described. They demonstrate that the facial or maxillary part of the skull was formed in the main after the Crocodilian type, but with well-marked Batrachian modifications in the intermaxillary and inferior maxillary bones. The most important fact which they make known is, that this Sauroid Batrachian had subterminal nostrils leading to a wide and shallow nasal cavity, extending horizontally backwards, and separated by a broad and almost continuous palatal flooring from the cavity of the mouth; which plainly indicates that their posterior apertures were placed far behind the anterior or external nostrils; whereas, in the air-breathing Batrachia, the nasal meatus is short and vertical, and the internal apertures pierce the anterior part of the palate, where they are readily closed and opened by the tongue in the act of swallowing the air.

But breathing by deglutition must have been as difficult, if not as impossible, in the *Labyrinthodons* as in the Crocodiles; and we may infer, therefore, that the apparatus for breathing by inspiration must have existed in the one as in the other. The inability to supply air to the lungs by deglutition is compensated for in the Crocodile by the power of dilating the cavity containing the lungs; which power is given by an apparatus of ribs encompassing the thorax and of their appropriate muscles. It may be reasonably anticipated, therefore, that the skeleton of the *Labyrinthodon* will be found to be provided with well-developed ribs, which,

if present at all in the existing Batrachia, exist only as straight and short rudimentary styles. Now the cause, or the essential condition of this defective state of the costal apparatus in the existing Batrachia is well known to be their fish-like mode of generation ; viz. the simultaneous development of their numerous ova, which demands a capacity and produces a distention and dilatation of the abdomen incompatible with the presence of the bony hoops which encompass that cavity in the reptiles that develope fewer ova, and mature them at successive intervals. Hence, if the structure of the nasal cavity of the *Labyrinthodon*, as displayed in two of the fossils here described, forbids the supposition that they breathed air after the manner of Batrachians, we may infer a Saurian condition of a part of their skeleton which has not yet been seen, and even gain considerable insight into the generative economy of a race of reptiles peculiar to one of the most ancient periods at which this order of vertebrate animals was called into existence.

Vertebra.—Of the bones of the trunk there exists in the present collection only a fragment of a vertebra referable to the *Labyrinthodon pachygnathus* (Pl. XLV. figs. 1–4.). The fragment in question consists of the upper part of the body of a vertebra, with the anchylosed neurapophyses, from which the transverse, the spinous and the posterior oblique processes have been broken away. The length of this fragment is two inches ; the breadth of the articular end of the body of the vertebra one inch three lines ; the upper half of this surface is preserved at the posterior part of the vertebra, showing that it is slightly concave, in which it deviates from the vertebral system of existing Saurians and anourous Batrachians, but corresponds with the vertebra of the *Labyrinthodon leptognathus* before described.

The fractured surfaces for the transverse processes show them to have been broad and thick at their origin ; they measure nine lines in antero-posterior diameter and four lines in vertical extent. Below the transverse processes the body of the vertebra is compressed and concave ; there is a small excavation at the anterior part of the base of each transverse process. The spinal canal is five lines broad and four lines high. The base of the spinous process is much contracted at the middle of the neurapophysial arch, from which point it has been based upon two distinct ridges, which thence diverge to the outer side of each of the anterior oblique processes. The articular surface on each of these processes is flat, and looks upwards and slightly inwards.

The concavity of the posterior articular surface of the centrum is demonstrated, and a like configuration of the anterior end may be safely inferred: thus, in the biconcave character of the vertebra, its lateral compression and smooth surface, the thickness of the transverse processes, and the size, shape and direction of the oblique processes, a close generic resemblance is manifested between the present vertebral fragment and the more perfect one of the *Labyrinthodon leptognathus* ; and the fissure at

the anterior part of the transverse process must be regarded as a corresponding structure with that more extensive fissure which separates the anterior part of the transverse process from the base of the oblique process in the smaller vertebra. It is, therefore, a modification to which attention should be paid in examining vertebræ or portions of vertebræ from the New Red Sandstone.

Bones of the Extremities.—The fossils to be noticed under this head are few, but significant.

I am disposed to refer to the anterior extremities the proximal end of a long bone (Pl. XLV. figg. 11–15.), which presents all the characteristics of the corresponding part of the humerus of a Toad or Frog; viz. the convex, somewhat transversely extended articular end, the internal longitudinal depression, and the well-developed deltoid ridge. This fragment, which includes perhaps the upper half of the bone, is two inches in length and thirteen lines in breadth; it diminishes, chiefly by the subsidence of the deltoid crest, to a subtrihedral shaft with the angles rounded off; it presents moderately thick compact walls, with a central medullary cavity. In this structure, as well as in its general form, the present bone agrees with the Batrachian and differs from the Crocodilian type.

Right Ilium.—The most complete bone in the present collection, not belonging to the cranial series, is the right ilium (Pl. XLV. figg. 16. and 17.), which presents, like many of the previously described bones, a combination of Crocodilian and Batrachian characters. It is nearly six inches in length, and is therefore most probably referable to the same species as the jaws last described. It supports on its anterior and outer surface the same proportion of the acetabular cavity as in the Crocodiles. This cavity is bounded on its upper part by a produced and sharp ridge, as in the Frog; which ridge is not emarginate at its anterior part, as in the Crocodile, but it subsides at the posterior part of the cavity, the surface of which is here continuous with the outer surface of the produced posterior part of the bone.

Above the acetabulum, in the Frog, the ilium gives off a broad and depressed process, the lower extremity of which is separated from the acetabulum by a smooth concave groove; there is no such process or groove in the Crocodile, but only a slight rising of the upper border of the acetabulum, against which the sacral ribs abut. In the present ilium there is a well-marked process in the analogous situation to that in the Frog, and separated also by a smooth concave surface from the upper edge of the acetabulum, but this process, instead of being depressed, is compressed and curved forwards; its internal extremity is pointed and bent, representing, as it seems, the rudiment of the long anterior process of the ilium in the anourous Batrachia. This process, in the *Labyrinthodon*, does not attain the parallel of the anterior margin of the acetabulum; and the bone terminates in a thick

truncated extremity a few lines anterior to the acetabulum, as in the ilium of the Crocodiles. The most marked character in which the present fossil deviates from the corresponding bone in the Crocodiles, is its extent posterior to the acetabulum: this part of the bone is compressed with a thick and rounded external and inferior margin; it becomes thinner and terminates in a fine edge internally and above; is slightly convex externally and concave on the opposite side, where it is also excavated by the articular surface for the sacrum.

In the Frog, as in the other tailless Batrachia, the ilium, besides being remarkable for its extreme length and slenderness anterior to the acetabulum, is also characterized by its mode of articulation to the vertebral column,—a transverse process of a single vertebra abutting against the anterior extremity of the produced ilium. In the Crocodile, on the contrary, the transverse processes of two vertebræ which are thickened and expanded, are joined to a rough concave articular surface occupying the inner side of the ilium opposite and a little posterior to the acetabular cavity. In some species the two articular surfaces are separated by a slight interspace; in others they are confluent, their respective proportions being indicated by an entering angle of the non-articulating surface of the bone.

In the fossil we find, as in the ilium of the Crocodiles, a well-marked, rough, elongated, concave articular surface divided by a corresponding but less produced angle of the non-articular surface of the bone, and unquestionably destined for the reception of the external extremities of at least two broad and strong transversely extended sacral ribs. It is continued from the process above the acetabulum upon one-half of the long posterior process: the length of this articular surface is four inches; its greatest breadth one inch three lines; the antero-posterior diameter of the acetabulum is two inches; its vertical diameter one inch and a half. In the Batrachia a broad and thin process is continued downwards and inwards below the acetabular cavity, representing the pubis, and this is separated from the acetabulum by a well-developed ridge and the concavity below it.

In the Crocodile, where the lower part of the acetabular cavity is always completed by the upper extremity of the pubis, the anterior and inferior part of the ilium offers an obtuse process at the posterior part of the lower boundary of the acetabular cavity: the *Labyrinthodon* agrees with the Crocodile in this structure. As the iliac bone here described was discovered in the same quarry with the two fragments of the cranium and the portion of the lower jaw of the *Labyrinthodon pachygnathus*; and as it presents a similar combination of Batrachian and Crocodilian characters, it may be concluded to have belonged to the same species and possibly to the same individual. The cranial fragments correspond in size with those in the head of a Crocodile between six and seven feet in length, but the ilium supports an articular cavity for the reception of the head of a femur, somewhat

greater than that exhibited by the same bone of a Crocodile twenty-five feet in length. If both belonged to the same individual, we should have an example of a reptile with hinder extremities of disproportionate magnitude as compared with those of existing Saurians, but which would approximate in this respect, as in many other particulars already pointed out, to some of the existing anourous Batrachians.

That such a reptile of a size equal and in some species far superior to that of the *Labyrinthodon*, to which the present fossils are here referred, formerly existed at the period of the formation of the New Red Sandstone, is abundantly manifested by the remains of those singular impressions of footsteps to which the term *Cheirotherium* has been applied.

Femur.—In the same quarry which yielded the above-described iliac bone, was found the hemispherical head of a femur, of a size corresponding with the articular cavity or acetabulum of that bone (it is figured, below the acetabulum, in Pl. XLV. fig. 18.). On the not improbable supposition that this is part of the skeleton of the same species of *Labyrinthodon* as that to which the humerus belonged, the relative size of these bones more nearly resembles that which must have characterized the so-called *Cheirotherium* than obtains in any recent Batrachian.

Phalanges.—The fossil from the Warwick sandstone figured as a tooth, in the memoir of Messrs. Murchison and Strickland (*loc. cit.* fig. 9. Pl. XXVIII.), differs from every known Saurian or Batrachian tooth in presenting a semi-elliptical transverse section, being flattened on one side and convex on the other, and being unusually curved. The unsymmetrical character of this fossil is so extremely rare a form in the simple conical teeth of reptiles, that I applied for and obtained permission to examine its intimate structure. The base of the fossil was fractured, but exhibited no trace of pulp-cavity. A transverse section taken from its middle, and viewed by transmitted light under a power of 200 linear dimensions, presented numerous parallel close-set Haversian canals, with concentric lamellæ surrounding each, and minute and simple radiated cells in the interspaces; there could be no doubt, therefore, that it was a true bone, and I conceive it to be most probably a terminal phalanx of a toe. It measures ten lines in length, is curved, and gradually diminishes in size from one end to the other. There is likewise in the collection a second terminal phalanx in the form of an elongated cone, with the articular surface slightly concave at the base; one side flattened, the opposite side convex; the apical extremity in both these phalanges is simply attenuated, but presents no trace of nail; they are strictly Batrachian in this respect, and from their size are referable to the hind-foot of the *Lab. pachygnathus.*

Thus then the fossils of the lower sandstones of Warwick and Leamington, though few, bear good testimony to the affinities of the reptiles of that ancient stratum. They all agree with each other and with the *Mastodonsaurus Jægeri*

of the German Keuper in their essentially Batrachian nature; for the well-marked and peculiarly complicated character of the dental structure admits of no doubt that the gigantic species of the Keuper-schiefer, with its Batrachian double condyle, is at least generically related to the *Labyrinthodons* of our own sandstones. With the deviations from the ordinary Batrachia manifested in the dental structure, and in the Crocodilian modifications and sculpturing of the cranium, it might reasonably have been anticipated that corresponding peculiarities should exist in the locomotive extremities, and fortunately we obtain a clue to this part of the organization of lost species by data independent of the osseous remains and more copious in the particulars which they reveal.

The New Red Sandstone has of late years contributed to the ichnological department of the history of extinct animals one of its most remarkable and problematical examples, in the footsteps of the so-called *Cheirotherium*. Without recapitulating the various conjectures to which these impressions have given rise, I may observe, that, adopting the opinion of Dr. Buckland and other distinguished geologists, that they were the foot-prints of an animal and not vegetable impressions, I have long entertained the opinion, and have expressed it in my lectures, that they were the foot-prints of a reptile and not of a marsupial or other mammal, and that this reptile most probably belonged to that family of the class which includes the Frog and other anourous Batrachia which offer a similar disproportion between the fore- and hind-legs. But, on the supposition of the Cheirothere being a Batrachian, it was not less evident that it was quite peculiar and distinct from any known Batrachian or other reptile in the form of its feet. The analogy of the Crocodilian reptiles would indicate the short and freely-projecting digit to be the outer or fifth toe, whilst the closer correspondence of the Batrachian feet would prove it to be the inner or first toe; but the thickness, relative size and position of the remaining toes are peculiarities of the Cheirotherian footsteps.

In the *Labyrinthodon*, however, we have a Batrachian reptile, and one that differs very remarkably from all known Batrachia and every other reptile in the structure of its teeth: it is also a Batrachian, which, with strong affinities to the Sauria, appears to have presented the same inequality of size between the fore and hind extremities as does the so-called Cheirothere: and both the footsteps and the fossils are peculiar to certain members of the triassic formations. May we not then be justified, upon this evidence, in adding the name *Cheirotherium* to *Mastodonsaurus* and *Phytosaurus* among the synonyms of the genus Labyrinthodon?

I have already alluded to footsteps of a different but somewhat allied form, as being probably those of the *Lab. leptognathus*. These footsteps actually occur associated with those of the *Cheirotherium* on the same slab, in the sandstone quarries at Storeton, but are more Crocodilian in their character.

If it should be proved that the *Lab. pachygnathus*, the larger and stronger-awed species, really had bones of the extremities corresponding with those that left the so-termed Cheirotherian impressions, while the impressions of the less anomalous form more closely agreed with the proportions of the osseous remains of the smaller and weaker species, the difference of the impressions will probably lead to a subgeneric separation. Be that as it may, the evidence that the fossils belong to one and the same natural Batrachian family is not thereby weakened. The progress of palæontological research may expand the application of the term *Labyrinthodon* to the family of Sauroid Batrachians; but at present, to avoid an unnecessary multiplication of names, I shall retain it as the generic appellative of the two British species and of the gigantic German *Salamandroïdes*, whose huge feet might well have fitted the impressions of the '*Cheirotherium Hercules*.'

Labyrinthodon Jægeri.

Lower Jaw.—Two considerable portions of the posterior half of the lower jaw of a large reptile, obtained by Dr. Buckland from the new red sandstone at Guy's Cliff, Warwick, have been referred to in his memoir and in that of Messrs. Murchison and Strickland, on the Warwickshire Sandstones. Both specimens are represented of the natural size in Plate XLVII. ; one (figg. 1, 1*) includes portions of the angular and dentary pieces ; the other (figg. 2 and 3.) is a considerable portion of the angular piece. This specimen exhibits on its outer surface (fig. 2.) the same bold sculpturing and radiated disposition of the grooves and ridges which characterize the bones of the cranium and upper jaw of the *Labyrinthodon*, figured in Pl. XLIII. figs. 1 and 9, and Pl. XLVI. fig. 6. But a more important evidence of the affinity of the Guy's Cliff fossil to the previously determined *Labyrinthodons* is given by the canal on the inner and upper part of the angular piece (Pl. XLVII. fig. 3.) for the reception of the dentary element. The specimen which includes part of the dentary piece still more satisfactorily establishes the generic identity of the large reptile of Guy's Cliff with the *Labyrinthodon* or *Mastodonsaurus*, by the size, mode of implantation, juxtaposition and alternate displacement of the serial teeth (Pl. XLVII. fig. 1*). From the analogy of the *Labyrinthodon pachygnathus*, the laniariform tusks at the anterior part of the jaw must have equalled in size those of the *Labyrinthodon Jægeri*, with which gigantic species of Sauroid Batrachian the British species represented by the Guy's Cliff fossils is, in my opinion, identical.

The description and figures of these most interesting fossils in the present memoir have been taken from plaster casts, which Dr. Buckland had, fortunately, caused to be made: the originals have been mislaid, and have, hitherto, been sought for in vain. Should they be recovered and the structure of the teeth be then examined by microscopic sections, I venture to predict, from the more obvious

characters in the casts, that those sections will confirm my deductions by presenting the peculiar labyrinthine structure. Between the *Labyrinthodon Jægeri* and the foot-prints of *Cheirotherium Hercules*, Egerton, the same correspondence of size exists as between *Lab. pachygnathus* and *Cheirotherium Kaupii.*

Labyrinthodon (Anisopus) scutulatus.

But though the evidence of more than one species of a distinct and peculiar genus of large Batrachians in the sandstones yielding the impressions of the *Cheirotherium* and other Reptilian footsteps be admitted to be valid, and the fossil remains be allowed to correspond in size with the animals which have left those footsteps, yet the opinion which I have formed from a comparison of the texture and markings of the bones, that the fragment of humerus and femur, and the iliac bone before described, belong to the same species, may not be received with the same implicitness ; since they were not discovered in such juxtaposition as would indicate them to have formed part of the same skeleton. Other evidence may therefore be demanded in proof of the proposition that the Labyrinthodont Batrachians likewise corresponded with the Cheirotherian footsteps in the small size of the anterior as compared with the posterior extremities.

A valuable contribution towards the required demonstration is afforded by the specimen, with the description of which the present paper terminates : this specimen (Pl. XLVI. fig. 1.) consists of a closely and irregularly aggregated group of bones, manifestly belonging to the same skeleton, and including four vertebræ more or less complete, portions of ribs, four long bones of the extremities, one end of a large flat bone, and several small dermal osseous scuta, all cemented together by a mass of soft sandstone. This highly valuable and unique fossil was discovered in the new red sandstone at Leamington, and was transmitted to me for examination in the course of last summer by Dr. Lloyd. Being at that time unacquainted with any other than the dental characters of the *Labyrinthodon*, I had no evidence of the relationship between that genus and the present fossil, for this presented no trace of teeth. I shall first give the notes which I originally took of this fossil, and afterwards enter upon the comparisons which prove it to belong to the same family, if not to the same genus, as the Warwickshire Batrachians.

The group of bones from the new red sandstone at Leamington belong to a small reptile with the biconcave system of vertebræ, but which, from the length, structure, and form of the long bones of the extremities, must have been of terrestrial rather than marine habits, and which had the skin defended by numerous small rhomboidal bony scutes, with a smooth central surface, and with the outer surface sculptured by three or four longitudinal ridges (fig. 5.). This reptile has had four legs, and the hind-legs have been at least twice as long and as

strong as the fore. Of the bones of these extremities there may be recognised a humerus, a femur, and the two tibiæ. The humerus (fig. 1, *h.*) is one inch in length, regularly convex at the proximal extremity, expanded both at this and the distal extremities, and contracted in the middle. There is a portion of a somewhat shorter and flatter bone, bent at a subacute angle with the distal extremity of the humerus, and which presents the nearest resemblance to the anchylosed radius and ulna of the Frog. Both the extremities are wanting in the femur (fig. 1, *f.*), the shaft of which is slightly bent, and is subtrihedral; its walls are thin and compact, and include a large medullary cavity. The tibia (fig. 1, *t.*) is as long, but thicker and stronger than the femur; both tibiæ have lost their articular extremities, but both exhibit that remarkable compression of their distal portion which characterizes the corresponding bone in the anourous Batrachia, and both likewise exhibit the longitudinal impression along the middle of the flattened surface; the length of the most perfect of these shafts of the tibia is two inches one line.

Associated with these bones is the extremity of a broad and compressed bone, which bears most resemblance to a portion of lower jaw, but does not afford the requisite characters for precise determination. The breadth of the entire end is one inch three lines; this is terminated by a gently convex outline; the fragment slightly contracts towards its broken end, which is one inch broad; one surface of the fragment is slightly convex; the opposite surface rises into a broad, obtuse, longitudinal ridge; the fractured surface exhibits a central medullary cavity, surrounded by a close cancellous structure, varying from one to two lines in thickness. If, as appears at first sight, it formed any part of the lower jaw, the proportions of the head of this Batrachian reptile must have been enormous; and the same disproportion opposes itself to the comparison of this bone with the expanded sacrum of the Toad, or with the scapula, coracoid, ischium or pubis, at least, if we take these bones in any known reptile as the standard of comparison. Nevertheless the deviations from ordinary proportions which extinct species occasionally present in parts of their skeleton, as *e. g.* the cervical vertebræ in the *Plesiosaurus*, the fingers of the Pterodactyle, &c., forbid the rejection of the idea, that the bone in question may have actually formed part of the same skeleton with the contiguous bones of the extremities and vertebræ.

The most perfect of these vertebræ is four lines in length; the vertical diameter of the articular extremity two lines, its transverse diameter one line and a half. Each terminal articular surface is pretty deeply and regularly concave, with the periphery convex: in two of the vertebræ these surfaces slope in a parallel direction obliquely from the axis of the body, as in the dorsal vertebræ of the Frog, and are not, as usual in Saurians, at right angles with that axis; so that they indicate an habitual inflection of the portion of the spine formed by them, analogous to that

which we observe in the humped or bent back of the Frog. But the vertebræ of existing caducibranchiate Batrachians have their posterior auricular surface convex, and are articulated, as is well known, by ball- and socket-joints: the biconcave vertebræ, therefore, of the extinct reptile under consideration would indicate its affinity with the more fish-like forms of the Batrachian order. The neurapophyses are anchylosed completely, without trace of suture, with the vertebral body, which is also a Batrachian character among existing reptiles:* they rise in the present fossil vertically and parallel with each other, are nearly coequal in length with the centrum, and are joined above by a broad and flat basis of the spinous process, from each angle of which the oblique or articular processes are continued; the surfaces of these processes are flat; the plane of the anterior ones looks upwards, that of the posterior ones downwards. A long and strong transverse process is sent off from each side of the base of the neurapophysial arch. The spinous process arises from the whole length of the middle line of the neurapophysial arch; it is not very high (about half a line); its chief peculiarity is the expansion of its elongated summit into a horizontally flattened plate, the sides of which slightly overhang the base of the spine; the upper surface of this plate is sculptured by irregular pits, and this character strongly indicates a similar structure of the flat bones of the cranium. The large atlas of the Toad presents a similar flattening of the summit of its elongated spine. The sides of the body of the vertebræ are smooth, concave in the longitudinal direction, owing to the lateral compression of the part below the transverse processes; the lower part of the body slopes inwards on each side to a median, inferior, slightly marked ridge.

In comparing these vertebræ with those of other reptiles, extinct and recent, although the biconcave structure is most prevalent in the species from strata below the chalk, yet the anchylosis of the vertebral arch, the obliquity of the centrum, the terminal expansion of the spine, and the depth of the articular depressions, indicate the Batrachian character of the present vertebræ. The aquatic Salamanders, including the gigantic species from Japan, and the great extinct Salamander of Scheuchzer, with all the Perennibranchiate Batrachia, have both extremities of the vertebra concave; but these concavities are generally conical, not hemispherical, as in the fossil: the neurapophyses in the fossil are higher, the spinal canal is deeper and wider, and the spinous process stronger and more expanded superiorly, than in the lower Batrachians.

The portions of ribs in the present fossil are few and small, but sufficient to indicate that the extinct reptile in question possessed them longer and more curved than in any existing species. Here then is demonstrated an important Saurian

* This structure prevails in the vertebræ of certain extinct Saurians.

modification of the thorax, which could only be inferred from the structure of the nasal cavity in the larger Labyrinthodons. And the light which the small reptile from the Leamington sandstone thus throws upon the organization of the larger Warwickshire Sauroid Batrachia is the more valuable on account of the correspondence of their vertebral characters, and of the proportions of their locomotive extremities. But the decisive evidence of dental structure is still wanting; nay, more, it may be objected that the Leamington fossil exhibits a character, in the small, bony, dermal sculptured plates, not yet found in the Warwick or Wirtemberg Labyrinthodons, which seems to remove it from all Batrachia—the naked reptiles, as they are emphatically termed,—and to approximate it to the Loricated order. Unquestionably these scuta form a striking instance of the Crocodilian affinities of the Leamington Batrachian; but we have already seen the same affinities manifested in other parts of their organization, by the Warwick and Wirtemberg Labyrinthodons. As these detached superficial bones are the most liable to be separated from the fragmentary skeleton of the individual they once clothed, the mere negative fact of their absence, when so small a proportion of the bones of the trunk of any *Labyrinthodon* has yet been found, is insufficient to prove a difference of dermal structure between the Leamington and Warwickshire species.

No anatomist, indeed, can contemplate the extensive development and bold sculpturing of the dermal surface of the cranial bones in the *Labyrinthodontes pachygnathus* and *leptognathus*, without a suspicion that the same character may have been manifested in bony plates of the skin in other parts of the body. And granting that this structure existed, to what extent, it may be asked, does it affect the claims of the *Labyrinthodon* to be admitted into the order of Batrachia, in which every known species is covered with a soft, lubricous and naked integument? To this question it may be replied, that the skin is the seat of the most variable characters in all animals; and, if considered apart from the modifications of the osseous and dental systems, is apt to mislead the naturalist who is in quest of the real affinities of a species. Suppose, for example, that the existing Chelonian reptiles were exclusively mud-tortoises, or with a soft and naked skin, as in the species of *Trionyx* and *Sphargis*, would the discovery of the osseous carapace of a true Testudo, in a fossil state, in connexion with a skeleton in other respects essentially corresponding with the modifications exhibited by a Trionyx, prohibit the association of the fossil in the same order of reptiles with the Trionyx, because of the indication of the scutes? It unquestionably ought not to affect such a determination. And so with respect to the Labyrinthodont Batrachia; if all the species have pushed their affinities to the Crocodilians so far as to have had their trunk defended by bony dermal plates, yet their double occipital condyle, their comparatively simple lower jaw, their large

palatal vomerine bones and teeth, and the other osteological characters already detailed, must still be deemed decisive of their essentially Batrachian nature.

If the evidence which I have been enabled to adduce in the present paper be compared with that previously recorded relative to fossils of the Batrachian family, the additions to this department of Palæontology will be found as follows :—

With the exception of the posterior fragment of the skull, on which Professor Jaeger's *Salamandroïdes giganteus* is founded, no Batrachian fossil had been detected anterior to the miocene tertiary period. The characters of Prof. Jaeger's fossil induced him to regard it as closely allied to the gigantic Newt or Salamander,—the *Homo diluvii testis* of Scheuchzer. It is placed between that fossil, which is the *Salamandra gigantea* of Herm. V. Meyer, and the *Triton Noachichus* of Goldfuss, in the 'Palæologica' of the former author. But the double condyle of the *Salamandroïdes* is a character also presented by the *Cæciliæ*, which some naturalists still class with the Ophidian reptiles. In the Catalogue of Fossil Batrachians* published by Dr. Tschudi, the *Salamandroïdes* of Jaeger is omitted: he commences his list by the statement, that, in epochs anterior to the Molasse, there is not, with certainty, known to be any trace of the fossil remains of Batrachia†. M. Tschudi, with many other continental palæontologists, although admitting the identity of the *Salamandroïdes* and *Mastodonsaurus*, place both fossils in the Saurian group.

The present researches afford additional evidence of the Batrachian character of the *Salamandroïdes* of the Alaunschiefer of the German Keuper; and they show that it is not merely a Batrachian, like the Salamander, but is a member of a peculiar family of Sauroid Batrachia, the more important characters of which were before unknown. It has now been demonstrated that this family, the species of which characterize and are peculiar to the new red sandstones, had a dental system differing from all other Batrachia in the inequality of size of the front and back teeth, the former being developed into great laniariform tusks; and that the teeth differ from those of all other animals in their peculiarly complex labyrinthine structure, whence the name of the family; which, at present, I use generically. The extinct Labyrinthodonts deviated from the Salamanders and other Batrachia in the Crocodilian development and sculpturing of the external and superior bones of the cranium, and in the structure of the pelvis, in which also they approximated to the Crocodiles: and one species certainly, and the others probably, receded from the Batrachia, in the same direction, in having dermal osseous plates.

* In the Mémoires de la Société des Sciences Naturelles de Neuchâtel, tom. ii. 4to. 1839.

† "Aus den der Molasse vorausgehenden Epochen, lassen sie mit Gewissheit keine spuren fossiler Ueberreste von Batrachiern nachweisen."—p 19.

The minor differences in the vertebræ and other parts noticed in the foregoing descriptions need not here be repeated, but sufficient has been recapitulated to show that the extinct Batrachians that characterize the new red sandstones once constituted a family of that order, hardly less remarkable or better defined in its characters than the equally extinct family of Enaliosaurs in the highest order of reptiles. It is not, perhaps, too sanguine an expectation to anticipate that subsequent researches may show that the Labyrinthodont family is not less rich in species, manifesting subgeneric modifications of the typical structure.

The following are those which at present are known :—

Labyrinthodon Jægeri.
——————— *pachygnathus.*
——————— *leptognathus.*
——————— *ventricosus.*
——————— *scutulatus.*

XXXIII.—*Memoir descriptive of a Series of coloured Sections of the Cuttings on the Birmingham and Gloucester Railway.*

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[Read June 10, 1840, and June 16, 1841.]

PLATE XLVIII.

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PREFACE.

A FEW years ago, when the various lines of railway in this country were first projected, it was usual to hear geologists congratulate themselves on the acquisitions which the science would receive from the numerous opportunities that would be thus afforded for studying the British strata. These anticipations have been in some degree fulfilled, but it is undeniable that during the last ten years many golden opportunities of studying geological phænomena and collecting specimens have been irrecoverably lost, in consequence of the railway sections not having been visited by geologists during the brief period when they were exposed to view. The practice commonly followed by engineers of covering up the "slopes" or sides of the cuttings with vegetable soil as soon as the excavations are completed, detracts greatly from the advantages which the science would otherwise derive from them; for unless some geologist happens to inspect the section at the right moment, the interesting phænomena which it discloses are buried for ever beneath the verdant

sod. The only remedy for this evil seems to be for each line of railway to be systematically surveyed by a competent geologist, who should pay repeated visits to every section during the time of its excavation, in order to collect minerals and fossils, and to record the features of its stratification. It would be highly desirable if each railway company had a professed geologist on its staff, but as such an appointment would probably be considered foreign to the objects of these companies, the ends of science might perhaps be attained if the Geological Society were to make applications to the several railway companies, requesting from them a series of their published sections, the colouring of which might be undertaken by some member of the Society. Such sections, even if uncoloured, are still valuable as containing a vast fund of accurate measurements, levellings, and other geographical facts, which it is desirable to possess in our archives. But, if the geological phænomena be superadded to these sections by the aid of colour, it is evident that such documents will acquire the utmost value. And we must remember that the means of doing this is fast passing away; in a few years all the important lines of railway will have been completed, and future geologists will perhaps sigh for the opportunities which their ancestors neglected.

Anxious to contribute towards so desirable an end, I gladly yielded to a request made to me by Captain Moorsom, chief engineer of the Birmingham and Gloucester railway, to undertake a geological survey of that line. To Capt. Moorsom the Society are indebted for the accompanying lithographed sections, to which I have added the geological colouring; and I must here express my obligations to that gentleman, as well as to Capt. J. Vetch, F.G.S., for much valuable assistance during the survey*. The line had previously been surveyed by Mr. F. Burr (see Geological Proceedings, vol. ii. page 593), and I am happy in bearing testimony to the general correctness of his observations; but as none of the excavations were commenced when he made his survey, he had no other data than the "trial shafts" sunk from time to time, which of course could not exhibit geological phænomena with the same accuracy as open cuttings†.

The Birmingham and Gloucester railway is not perhaps geologically one of the most interesting lines, because, from running nearly parallel to the strike of the strata, it passes through but a small succession of formations. This circumstance, however, causes each stratum to be exposed in greater detail, and affords a wider scope for local variations.

* The sections here referred to, consisting of thirty-five folio sheets, are deposited in the Society's Collection of Maps, &c.

† The lithographed sections being made for engineering purposes alone, exhibit a great disproportion between their vertical and horizontal scales; the former exceeding the latter in the ratio of about 13 to 1. In the portion of these sections introduced in the Plate this disparity is diminished one half.

Description of the Deposits.

§ 1. *New Red Sandstone.*—The geological starting-point on this railway does not coincide with either of its locomotive termini. The lowest rock exposed is on the anticlinal axis of the Lickey, about ten miles S.S.W. of Birmingham. It will be remembered, that in the description given by Mr. Murchison of the Bromsgrove Lickey *, the effects of that trappean eruption are stated to extend many miles towards the S.S.E. in the shape of a long elevated tract called the Ridgeway, forming the western watershed of the river Arrow. The transverse sections of this ridge, afforded by the railway as well as by the Birmingham and Worcester canal a mile further south (see Burr, Geol. Proceedings, vol. ii. p. 594), sufficiently prove an anticlinal arrangement of the strata.

The cutting No. 95.† on the engineering section‡ crosses the anticlinal ridge of the Lickey, and being excavated to the great depth of fifty-six feet, it was naturally expected to exhibit some points of interest. About half a mile to the north of it, trap rock appears *in situ* §, elevating and altering the Caradoc sandstone or Lickey quartz. Neither of these rocks, however, appear in the railway excavation, which exhibits nevertheless clear proofs of the disturbance attending the upheaval of the Lickey.

The lowest rock visible in this cutting is a mass of very hard brownish or reddish sandstone, commencing about fifty yards to the east of the post which marks the railway summit, and extending about seventy yards to the eastward, where it attains the height of twenty feet above the railway, and is suddenly cut off by a nearly vertical fault (see section, Pl. XLVIII. figs. 1, 2.). Some of the beds of this sandstone are of a grey colour and uniform compact texture, with specks of white decomposed felspar; others are coarser-grained and of a brown or reddish tint, containing rolled fragments of ferruginous or dark red indurated marl. No organic remains were noticed in it, and it hence becomes difficult to fix the precise age of this rock. I at first considered it to be a portion of the Caradoc sandstone of the Lickey, but from a closer inspection of its mineral characters I should prefer classing it in the "Lower New Red Sandstone" of Mr. Murchison.

The strata of this rock dip at the high angle of about 60° to E.S.E., or *from* the great mass of trap composing the Upper Lickey (see Mr. Murchison's map).

The rock above described is overlaid *unconformably* by a vast mass of conglomerate belonging to the "Upper New Red" or bunter sandstein. The latter deposit

* Silurian System, p. 569.

† The account of this cutting was read June 16th, 1841.

‡ See sheet 24 of the lithographed sections.

§ See Silurian System, p. 495.

exhibits an imperfectly anticlinal arrangement*. On the east of the fault above mentioned, it dips about 5° to E.S.E., while on the western side its dip may be estimated at about 5° to the S.S.E. or S. The bedding is however so irregular that great accuracy on this point is not attainable, but it will suffice to state, that the stratification never departs far from horizontality, and is hence most strongly contrasted with that of the highly inclined sandstones above described, on which the conglomerate reposes.

The cutting here described affords a rare opportunity of inspecting the conglomerates of the upper new red sandstone. For the depth of nearly sixty feet the section consists almost exclusively of rounded pebbles imbedded in soft red sand. The resemblance of this deposit to ordinary diluvial gravel is so perfect, that when the excavations were first begun, I considered it as such, and it was not till the completion of the cuttings, that I became undeceived. The gravel is now not only seen to contain numerous wedge-shaped masses of red sandstone and red marl (exhibited in the section, Pl. XLVIII. fig. 2.), but it is further shown to underlie the regular thick-bedded sandstone at each end of the section, so that its antiquity is thus most clearly proved.

From this stratum of new red conglomerate a large portion of the superficial or diluvial gravel of the surrounding counties has evidently been derived. At least nine-tenths of the pebbles of the conglomerate consist of quartz, either white and crystalline, or brown and granular, the latter doubtless derived from altered sandstones, such as are still seen *in situ* at the Lickey. The remaining portion of the pebbles includes various trap rocks, chiefly porphyritic, which are often decomposed into the condition of clay. Boulders of a hard quartzose conglomerate, probably derived from the old red system, also occur, together with pebbles of chert inclosing casts of Spirifers and Crinoidea†. The beds of conglomerate are interspersed and dove-tailed with bands of soft red sandstone, loose sand, and occasionally red marl, in the manner represented in fig. 2. Pl. XLVIII. At each end of the section, the conglomerates are seen to be overlaid by beds of massive red sandstone, varying in texture from a compact rock to a loose sand, which again appears about a mile to the S.W., in the cutting No. 89, at the top of the inclined plane.

The point which appears of the greatest interest in the section here described, is

* The arrangement of the new red sandstone on the south side of the Lickey is more properly *mantle-formed* than *anticlinal*. On the line of the railway the dip sweeps round from E.S.E. to S.S.E., S., and W.S.W.

† These fragments of chert appear to indicate a considerable transporting power in the sea which deposited the new red conglomerate, no chert being now known nearer than Derbyshire, a distance of about fifty miles from the Lickey.

the *unconformability* of the lowest rock, above mentioned, with the overlying new red conglomerate. Assuming that the lowest rock is correctly identified with the "Lower New Red," it follows that we thus obtain a tolerably exact date for the principal protrusion of the volcanic rocks of the Lickey. The sandstone in question dips at the high angle of 60° directly from the trap rocks, which exist *in situ* a short distance to the north-west, and it is overlaid by conglomerates which are not far removed from horizontality. It is therefore clear, that these trap rocks must have been erupted *after* the deposition of the lower new red, and *before* the conglomerates of the upper new red, and it is probable that the rolled pebbles of the conglomerate were derived in great measure from the shattered strata which were thus upheaved in the immediate vicinity*. It is further to be inferred, that additional elevations of the region of the Lickey took place at a later date, for we find these overlying conglomerates traversed by a fault, and upheaved into an anticlinal position, which may be traced on each side of the ridge as far up in the series as the saliferous marls. Indeed it is probable that some of the dislocations connected with the Lickey were later than the age of the lias, for in the south of Worcestershire and Warwickshire the lias and red marl are affected by several extensive faults, the directions of which have an appearance of *radiating* from the Lickey. (See Geol. Trans. vol. v. pp. 333, 335.)

In Groveley Hill (fig. 1.), on the north-east of the Lickey ridge, the red sandstone passes occasionally into a hard conglomerate of quartz pebbles with a calcareous paste, forming nodular masses and thin strata. Similar conglomerates are described by Mr. Murchison as occurring in the upper new red sandstone in several parts of Worcestershire, Staffordshire and Warwickshire†. A considerable dislocation appears to traverse this hill, for, at the north end of Groveley Tunnel, the strata dip about 30° N.E., while at the south end the inclination is only about 3° S.E. (See the section, Pl. XLVIII. fig. 1.)

At Finstal, on the south-west flank of the Lickey ridge, the upper portion of the sandstone becomes light-coloured, contains obscure vegetable impressions (fig. 1, upper line), and is a prolongation of the stratum of light-coloured sandstone with vegetables exposed at Breakback Hill on the west of Bromsgrove‡. These decomposed fragments of plants form the only examples of organic remains exposed by the railway-cuttings in the new red sandstone.

* The age here assigned to the trap rocks of the Lickey coincides with that attributed to them as well as to those of Abberley and Malvern by Mr. Murchison (Silurian System, p. 67), though I believe he had nowhere noticed an example of unconformity between the upper and lower new red, such as is here exhibited. The elevation of the Nuneaton district seems also referable to the same epoch.

† See Silurian System, p. 42, and Geol. Trans. 2nd Series, vol. v. p. 347.

‡ See Geol. Trans. 2nd Series, vol. v. p. 341.

§ 2. *Red Marl.*—The red or Keuper marl overlies the new red sandstone on each side of the Lickey ridge. On the north-east it is traversed by the line of railway from Groveley Hill to Birmingham, which town stands on the new red sandstone, but is closely skirted by red marl on the south and east. The same formation extends from Birmingham along the London railway as far as Berkswell, forming, in North Warwickshire, a basin of red marl with the small lias outlier of Knowle in the centre*. This great extension of red marl was not known at the time of the construction of Mr. Murchison's map, in which the new red sandstone of Warwickshire is carried too far to the southward. The true boundary of the marl and sandstone ranges from Hewell Grange nearly north by Cofton Hacket to Northfield, and thence north-east to the south suburbs of Birmingham. The course of the railway is nearly parallel to this boundary line.

On the south-west side of the Lickey ridge, the new red sandstone becomes marly and thin-bedded in the upper part, and eventually passes into the incumbent red marl. The latter retains an inclination of 6° to 8° south-west, resulting from the elevation of the Lickey ridge, till we reach the salt-works at Stoke Prior†. The deep excavation made at this place is fully described by Mr. Murchison (Sil. Syst. p. 31), and I will therefore only remark, that, from the dip of the strata exposed by the railway, it is evident that the position of the salt rock must be near the bottom of the marl immediately above the sandstone.

The red marl presents no other feature of importance till we reach the neighbourhood of Hadsor, where the railway crosses a promontory of lias projecting from the main body of that formation (Pl. XLVIII. fig. 3.). On the north side, the marl is cut off by a fault, but on the south, at Dunhamstead, is an interesting section of the junction of the two formations.

The following section is here exposed:—

a. Lias clay, with contorted beds of lias limestone containing saurian bones.
b. White micaceous sandstone, two feet.
c. Lias clay, six feet.
d. Grey marl, thirty-five feet.
e. Red marl.

The whole dipping 5° N.N.E.

The sandstone *b* has much resemblance to the "Keuper sandstone" described in Geol. Trans. vol. v. p. 332, but it occurs considerably higher in the series. It here contains numerous specimens of a smooth oval bivalve, larger and more oblong than the *Posidonomya minuta* of the Keuper (Geol. Trans. vol. v. Pl. XXVIII. fig. 4.),

* See Geol. Trans. 2nd Series, vol. v. p. 336.

† See sheet No. 20 of the Railway Section, and Plate XLVIII. fig. 1, upper line.

but too imperfect to exhibit generic characters*. In the hill south of Dunhamstead is a fault which causes the grey marl to abut against the red, as seen in the Railway section, sheet 17, and Pl. XLVIII. fig. 3. of this volume.

For the next five miles the railroad runs through red marl in a valley between the escarpment of the lias and a ridge caused by the "Keuper sandstone." On the south-east of Spetchley† is a dislocation which causes the Keuper sandstone to change its strike from south by east to south-west, forming a projecting angle which is intersected by the railroad. The stratum is here but a feeble representative of the Keuper sandstones of Burg Hill, Inkberrow, and Shrewley‡, consisting chiefly of greenish marl with thin laminæ of white sandstone, the whole forming a deposit of about twenty feet thick, with red marl both above and below. The bands of sandstone vary rapidly in thickness, and one wedge-shaped solid mass, about thirty feet long, is two feet thick in the middle, and thins out entirely at each end.

§ 3. *Lower Lias.*—About a mile further south, at Norton§, the railway traverses the lias escarpment, which presents a section exactly analogous to that at Dunhamstead, showing the same succession of lias-limestone, clay, white thin-bedded sandstone, grey marl, and red marl. The sandstone also contains the oval bivalve met with at Dunhamstead.

About a mile south of this point, the lias clay contains many calcareous concretions abounding with shells, including *Plagiostoma giganteum*‖, *P. duplicatum*, *P. Hermanni*, Goldf., *Terebratula ornithocephala*, *Modiola minima*, and a *Caryophyllæa*, which is remarkable from the general scarcity of corals in the lias formation. Further south, near Abbott's Wood, the beds of fissile sandstone at the base of the lias are again exposed on the railway, being brought up by a fault. Thence the lias clay presents little interest till we reach Defford (Pl. XLVIII. fig. 5.), where numerous specimens of *Pachyodon*¶ *Listeri* (Stutchbury, Annals Nat. Hist., March 1842) (*Unio Listeri*, Sowerby), *Gryphæa incurva*, *Astarte lurida*, *Plagiostoma punctatum*, *P. duplicatum*, and several apparently new species of Ammonites, Modiola, &c., occurred in the cuttings.

The same shells are found also at Eckington (fig. 5.), on the south of the Avon; but at Bredon (fig. 5.) we reach a higher stratum of the lias clay, and meet with an almost entirely distinct set of organic remains, among which *Pleurotomaria Anglica*, *Hippopodium ponderosum*, *Gryphæa Maccullochi*, *Nautilus striatus*, *Phola-*

* In a paper read December 1841, I have shown that this band of sandstone is the true equivalent of the "Bone-bed" of Somerset and East Devonshire. Note, 1842.

† See sheet No. 14, and Plate XLVIII. fig. 4.

‡ See Geol. Trans. 2nd Series, vol. v. p. 332 *et seq.* § See sheet No. 13, and Plate XLVIII. fig. 4.

‖ All the shells included in this and the following lists are described in Sowerby's Mineral Conchology, unless a different authority is given.

¶ The name *Pachyodon* having been previously used by Von Meyer for a vertebrate genus, should here be superseded by the term *Cardinia* of Agassiz.

domya ambigua, *Modiola scalprum*, *Plagiostoma punctatum*, *P. duplicatum*, *Plicatula spinosa*, *Spirifer Walcotti*, *Corbula cardioides* (Phill.*), *Amphidesma donaciforme* (Phill.), *Pecten sublævis* (Phill.), *Ammonites planicosta*, *A. obtusus*, *A. Turneri*, *A. Conybeari*, and *A. Birchi*, have been identified. Between Bredon and Cheltenham the ground is very level, and but few sections of importance occur; but at the latter town, and between it and Gloucester, the excavations in the lias clay are very extensive, and have supplied large collections of organic remains to the cabinets of the Cheltenham geologists.

Some of these fossils are enumerated in Mr. Murchison's memoir on the Geology of Cheltenham, but a considerable number of species, especially of Ammonites, appear to be new, as I have been able as yet to assign names to only the three following:—*Ammonites armatus*, Sow., *A. ovatus*, Young and Bird†, and *A. lenticularis*, Young and Bird. With the exception of the *Hippopodium ponderosum*, *Gryphæa Maccullochi*, and one or two others, the Cheltenham fossils are wholly distinct from those of Bredon, proving how small a difference of vertical position will effect an almost total change of organic remains. At Hewlitts, east of Cheltenham, the lias near the base of the marlstone presents another series of distinct fossils, consisting of *Hippopodium ponderosum* (rugose variety, perhaps a distinct species), *Modiola scalprum*, *Spirifer granulosus*, Goldf., *Terebratula rimosa*, Bronn‡, *Perna ventricosa*, *Pachyodon attenuatus*, Stutchb., *Littorina imbricata* (*Trochus imbricatus*, Sow.), *Ammonites Henleyi* (*A. striatus*, Rein., *A. heptangularis*, Young, *A. Cheltiensis*, Murchison §), &c., so that in the lower lias alone we have evidence of at least five well-marked successions of molluscous faunæ ranging through a vertical height of about 400 or 500 feet, and unaccompanied by any change in the mineral character of the deposit.

Having now described the secondary formations along the line of the railway, we will recommence at the Birmingham end, and examine the deposits of superficial detritus.

The phænomena exhibited by the railway cuttings are entirely confirmatory of the views which I have announced elsewhere‖ respecting the distinction between those ancient terrestrial alluvia in which mammalia occur and the general mass of submarine drift which covers most parts of the island. In pursuance of these views, the ancient superficial detritus of this district may be divided, according to its efficient cause, into *fluviatile* and *marine*; the latter, according to its origin, into local and erratic; and this again, according to its composition, into gravel *with flints* and *without flints*.

* Geol. Yorkshire, Part 1. † Geological Survey of the Yorkshire Coast, 4to, 1828.

‡ Lethæa Geognostica, p. 292, Taf. 18, f. 6.

§ Outline of the Geology of the neighbourhood of Cheltenham, 1834.

‖ See Report of British Association, vol. vi. Sections, p. 61.

§ 4. *Marine erratic gravel without flints.*—This detritus occurs at intervals along the railway from Birmingham till the line approaches the valley of the Avon. Vast accumulations of it (the "Northern drift" of Mr. Murchison) occur on all sides of Birmingham. My own personal inquiries addressed to resident geologists, railway engineers and excavators, aided by printed queries circulated in the Geological Section of the British Association* at Birmingham, all tend to prove the *utter absence* of mammalian remains in the deposits of this class in that neighbourhood. Chalk flints, though not absolutely wanting in the Birmingham gravel, are yet so extremely rare, as to prove that the current which transported it came from the north, and not from the east, and furnish a well-marked distinction from the flinty gravel described below.

At Mosely the railway is cut through a vast deposit of this gravel upwards of eighty feet thick, reposing upon red marl†. It is composed of rolled pebbles, rarely exceeding four inches in diameter, of various granitic and quartzose rocks and altered sandstones, imbedded in clean ferruginous sand devoid of argillaceous matter. A stratum of sand about thirty feet thick, free from pebbles, occurs in the middle of the gravel.

Between Mosely and the Lickey the railway-line is in general free from gravel. The only mass of stone of sufficient size to deserve the name of an erratic block occurred on the line of the railway between Cotteridge and Wytchall‡, and reposes on the red marl. It is shapeless, about five feet by four, with the angles partially rounded, and consists of greyish porphyritic trap.

Patches of gravel of this class occur on each flank of the Lickey ridge, though none, as before shown, were found on its summit at the part traversed by the railway. The singular manner in which the gravel reposes on an irregular surface of new red sandstone is shown in the cutting at the summit of the inclined plane, Pl. XLVIII. fig. 1. This superficial drift closely resembles the genuine new red conglomerate seen in the cutting on the Lickey ridge, as it consists in great measure of the same materials, but it may be distinguished by containing, in addition, many fragments of slaty rocks, and by the sand in which the pebbles are imbedded being freer from red argillaceous matter, and consequently of a whiter colour. This gravel attains on the line of the railway a height of 544 feet above the sea (not 387, as misprinted, or 587, as corrected in the Proceedings, vol. iii. p. 316). I may here remark, that the gravelly soil of the Lickey Beacon, 900 feet high, which has been quoted as an example of superficial gravel at a great elevation, may very probably not be derived from these recent or "diluvial" deposits, but from the genuine new red conglomerate, though its existence *in situ* cannot be de-

* See Report of British Association, 1839, Sections, p. 71.

† See sheets 30 and 31.

‡ See sheet 28.

termined in consequence of the want of sections. For the present, therefore, the above-mentioned elevation of 544 feet is the greatest which can be assigned with certainty to the superficial gravel or "Northern Drift" of this part of England.

The next locality where gravel occurs is at Sugars Brook*. This deposit consists of quartzose pebbles, commonly less than three inches in diameter, and rarely equal to six. No stratification is observable. The surface of the bed is about twelve feet above the brook, and from its low position it appeared likely to belong to the fluviatile class, and to contain mammalian bones; but though many thousand tons of gravel have been raised for the use of the railway, I have not been able to learn that any organic remains have been found in it.

From this point no more gravel occurs on the line of the railway for the next sixteen miles; but a few hundred yards east of it, at Abbott's Wood, is an extensive deposit of quartzose gravel, mixed with ferruginous sand devoid of flints, and resting upon lias clay. Here also large quantities of gravel have been extracted, but the evidence of the engineers and workmen is unanimous as to the absence of organic remains.

§ 5. *Marine erratic gravel with flints.*—It was stated in a paper read at the Liverpool meeting†, that the gravel to the south-east of the Avon in Warwickshire and Worcestershire abounds in flints, indicating a current from the chalk district lying to the eastward, and accordingly no sooner does the railroad pass that river than we find a very large per centage of flints in the gravel. The village of Bredon stands on a platform about seventy feet above the ordinary surface of the Avon, capped with an extensive deposit of this kind of gravel from ten to fifteen feet thick‡. It reposes on an uneven surface of lias, and is mixed with much ferruginous clay. Its height above the Avon valley, though slight, has been sufficient to protect it from the modifying effects of fluviatile agency, and hence the extensive excavations near Bredon have furnished no example of mammalian bones.

§ 6. *Fluviatile gravel.*—The only instance of this description of detritus on the railway-line is on the two flanks of the Avon, at Defford and Eckington§. On either side of the river is a tabular platform, the surfaces of which do not exceed *forty-five* feet above the Avon; and they are capped by about ten feet of gravel, precisely similar in composition to the flinty gravel of Bredon, but with this important difference, that it contains an abundance of mammalian remains. These were found chiefly in the cutting in the north of the village of Eckington. The bones occur principally at the lower part of the gravel, and often on the surface of the subjacent lias clay, about thirty-five feet above the river. They are accompanied with numerous freshwater shells, agreeing in species with many of those enumerated

* See Plate XLVIII. fig. 1, upper line.

† See Report of Brit. Assoc., vol. vi. Sections, p. 62.

‡ See sheet No. 7. and Plate XLVIII. fig. 5.

§ See sheet No. 9, and Plate XLVIII. fig. 5.

in Mr. Murchison's Silurian System (p. 555) as found in a similar position at Cropthorne, a few miles higher up the Avon. The most abundant species are the *Cyclas amnica* and *C. cornea.* Great numbers of the bones have been broken and lost by the carelessness of the workmen; but those which have been preserved, and which are in the cabinets of the Worcestershire Natural History Society, of Mr. Fowler of Cheltenham, Mr. Dudfield of Tewkesbury, and my own, are referable to *Elephas primigenius*, *Hippopotamus major*, *Bos urus*, and *Cervus giganteus?*

On the north or opposite side of the Avon, about twenty feet above the river, bones of *Elephas primigenius*, *Rhinoceros tichorhinus* and *Hyæna spelæa*, accompanied with freshwater shells, occur beneath a few feet of gravel and under similar circumstances to those at Eckington.

In endeavouring to account for the presence of freshwater shells and bones at this part of the railway-line, and their absence in all other portions of the district described, I can offer no other explanation than that formerly proposed*, viz. that *after* the beds of marine gravel had been deposited where we now find them, and had been laid dry by the elevation of the land, a large river or chain of lakes extended down the valley of the Avon at a height of from twenty to fifty feet above its present course, and that the gravel previously brought into the district by marine currents was remodified by the river-stream and mixed up with remains of Mammalia and Mollusca which tenanted its banks or its waters.

§ 7. *Local gravel.*—This occurs abundantly at Cheltenham†, and consists exclusively of detritus from the oolite and lias of the vicinity‡. The composition varies from the state of gravel to fine calcareous sand. No bones or other terrestrial remains have occurred in it, and it is therefore referred, in the absence of other evidence, to a marine origin.

§ 8. *Modern alluvia.*—No formations of any importance belonging to this class occur on the line of the railway, except the peaty deposits on the banks of the Avon and its tributary streams. In sinking through this peaty soil for the foundation of the bridge over the Avon at Defford, a human skeleton was found at the depth of eighteen feet from the surface.

Conclusion.—On a general review of the sections afforded by the Birmingham and Gloucester Railway, although they do not present us with any very striking or novel phænomena, yet we may justly attach some value to the evidence they afford of geological facts, whether as confirmatory or as corrective of those previous researches which were undertaken without the assistance now furnished by the railway cuttings. In conclusion, let me again express a hope that the time is not far distant when this Society may be in possession of a set of coloured sections of every railway in the kingdom.

* See Report of Brit. Assoc., 1837, vol. vi. Sections, p. 64. † See Railway Sections, sheet No. 1.

‡ See Mr. Murchison's Outlines of the Geology of Cheltenham, p. 28.

XXXIV.—*Notes to accompany some Fossils collected by the Author, and* Mr. H. Still, F.G.S., *during their employment on the Ordnance Survey in Pembrokeshire.*

By HENRY MACLAUCHLAN, Esq., F.G.S.,

Employed on the Ordnance Survey.

[Read June 16, 1841.]

IT may be proper to state, that it is owing to the encouragement held out by Colonel Colby to notice objects connected with science, where so doing does not interfere with the progress of the survey, that these fossils were collected.

In Mr. Murchison's work on the Silurian System the rocks of South Pembroke are described, and some general observations are made on those of North Pembroke; and in his map the lower beds of the Llandeilo Flags range from Camrose on the west to Llandewy Velfry on the east.

Taking this line as a base for our observations, commencing at Llawhaden, a little north of Canaston Bridge (fig. 2. p. 559), where the dip is northerly, and proceeding towards Precelly Mountain, we cross a conglomerate, which may be traced in a westerly direction to Ford, where it is found in contact with the trap; and in an easterly direction towards Llangan, where a stratified, conglomerate sandstone occurs, containing species of Trilobites and of Orthis or Spirifer.

To this conglomerate succeed first sandstone and sandstone shales, dipping to the north; and then, nearer Clarbeston, carbonaceous shales, containing casts of fossil shells and Graptolites, overlaid by limestone. The line of section afterwards crosses another bed of sandstone, which is succeeded by roofing-slates that extend nearly to Llys-y-frân.

Similar carbonaceous shales may also be seen to the west of the line of section at St. Catherine's Bridge, near Camrose, and at Rudbaxton; also at Long Ford, south of Llandysilio, to the east of the section.

These shales bear so strong a resemblance to the coal-measures, that unsuccessful excavations have been made in them at Rudbaxton, Clarbeston, and Clynderwen, south-east of Llandysilio.

Indications of an anticlinal line may be seen near Narberth and Camrose, also

at Solfach, to the south-east, and Porthlliskey, to the south-west of St. David's; at the latter village the dip becomes westward, and continues changing to Whitesand Bay, where it assumes a northerly inclination, as may be observed at St. Lawrence, thirteen miles east of St. David's Head, Leweston, three miles south of St. Lawrence, Camrose, and Long Ford, about two and a half miles south of Llandysilio; the line is broken at Roche, five miles south-west of St. Lawrence, and at Leweston by the intrusive trap.

Graptolites were found at Robleston, in the parish of Camrose, in calcareous shales, near their junction with the trap of Plumstone.

Resuming the section at Llys-y-frân and proceeding towards Dinas Head, roofing-slates alternate with trap, decomposed on the surface, and masses of apparently intrusive greenstone are likewise visible: these traps and slates have been traced for miles to the east and west of the line, the schists dipping with remarkable uniformity to the north. This would lead to the supposition that the trap was contemporary with the slates, but the cursory view obtained on the surface prevents any certain conclusion being formed.

The slates at Abereiddy Bay (sect. fig. 1.) contain Graptolites, as observed by Professor Sedgwick; and two species appear, from Mr. Lonsdale's examination, to be identical with the *Graptolithus Murchisonii* and *foliaceus* of the Llandeilo Flags.

In the same bay are found numerous specimens of an Euomphalus, which bear some resemblance to one of the specimens represented by fig. 13. Plate XXII. of the Silurian System; also specimens of a Lingula, but distinct from the Llandeilo Flags, species figured by Mr. Murchison.

The beds, which are worked for roofing-slate at Abereiddy Bay, are inclined highly to the north, the line of bearing being from north-east to south-west; and though they differ in mineral character, as well as dip, from the general inclination of the Llandeilo Flags, yet this difference may have been produced by the action of the trap, which intersects them in a north-east and south-west direction, and between Abereiddy and St. David's occupies nearly the whole surface.

Overlying these slates, to the north, but with many beds of trap, slates, and sandstones between them, having the prevailing northerly dip, we find the conglomerate of Dinas Head (fig. 1.), Newport Bay, and Trewiddel, near Cardigan, composed of fragments of various rocks, cemented by a grit of trappean aspect, and resembling certain conglomerates described by Mr. Murchison as occurring in the Caradoc sandstone.

The organic remains hitherto obtained from these beds are not very satisfactory, but the most prevailing fossil is the cast of a crinoidal stem, composed of numerous thin joints with interspaces at irregular distances; the best specimen of which, procured at Trewiddel, near Cardigan, Mr. Lonsdale considers analogous to speci-

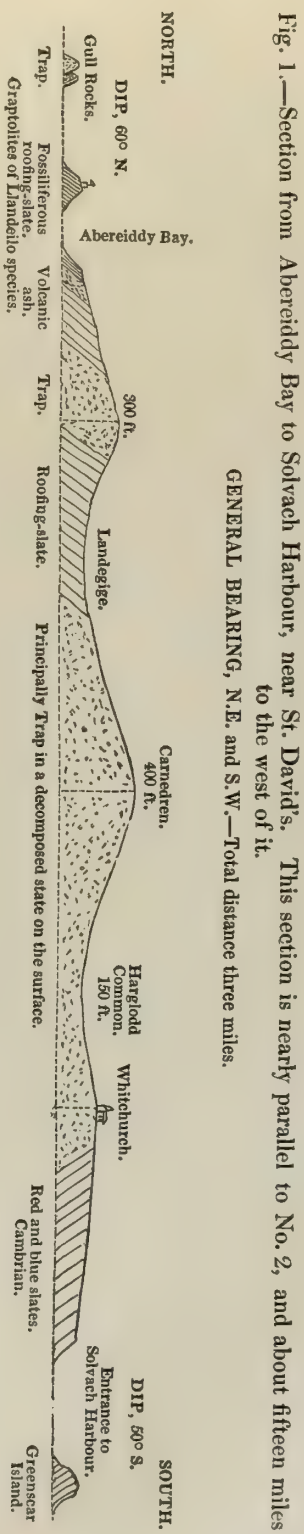


Fig. 1.—Section from Abereiddy Bay to Solvach Harbour, near St. David's. This section is nearly parallel to No. 2, and about fifteen miles to the west of it.

GENERAL BEARING, N.E. and S.W.—Total distance three miles.

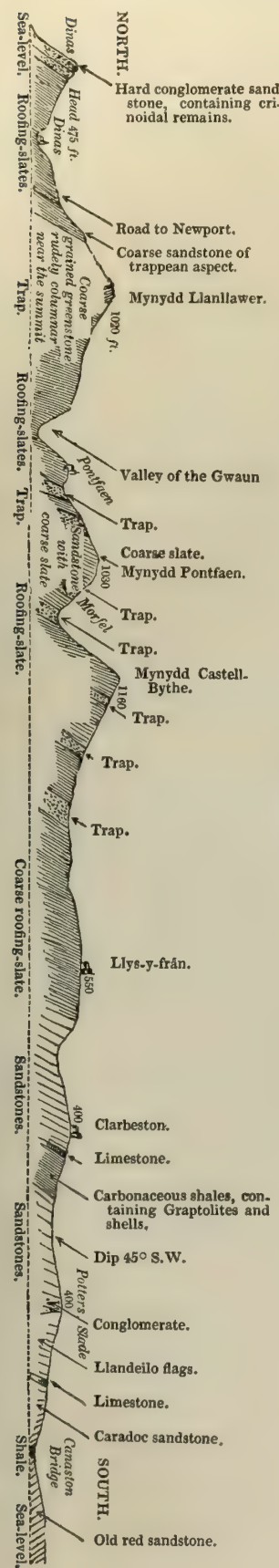


Fig. 2.—Section from Llawhaden, near Canaston Bridge, on the south, to Dinas Head, on the north.

Total distance.

mens obtained by Mr. Murchison from the Caradoc sandstone, at Little London, May Hill, and Corton near Presteign. See Silurian system, pl. 20. fig. 19.

This conglomerate commences at Dinas Head, and crossing Newport Bay, continues to the hill above Trewiddel, near Cardigan, and probably further.

It does not appear to be disturbed by igneous rocks.

Trappean ash is found near the conical elevations of intrusive greenstone at Penbury Hill, two and a half miles north-north-east of St. David's, Llanllawer, two miles south-east of Fishguard, and Carningley, one mile south of Newport.

It is provincially called toughstone, and is worked as a building material, being soft when first raised, but hardening by exposure to the air, and very durable. Though the summit of the principal elevation of the Pembrokeshire chain is not trap, but roofing-slate, yet beds of trap extend nearly to the top, and are continuous apparently throughout the district, having masses of more decided greenstone occasionally protruded through them.

These beds may be traced to Plumstone Mountain, five miles north-west of Haverfordwest, and to St. David's Head, and thence through "The Bishop and his Clerks Rocks," and the dangerous rocks called "The Hats and Barrels," to the rock of "The Smalls Lighthouse."

On the north-east of the chain, at Whitchurch (Eglwyswen), six miles north-east from Newport, on the east at Llanfirnach (Llanfrynach, Ord. Map), and on the south at Llanglywdwen, are beds of a dark carbonaceous shale, which apparently overlie and mantle round the trap rocks, yet still preserve the northerly dip. These beds have been worked unsuccessfully for culm, and are accompanied by lead veins, one of which at Llanfirnach has proved to be profitable.

At Llanglywdwen Bridge are indications of copper, and a considerable bed of limestone is in contact with the lode.

Mineral veins were also observed along the coast, from Newgate in St. Bride's Bay to St. David's Head.

At Fishguard and Strumble Head are basaltic columns, and at Llanwnda a jasper vein, and veins of green compact felspar.

May 1841.

XXXV.—*Notice of the Discovery of a mass of Trap Rock in the Mountain Limestone of Bleadon Hill, in the County of Somerset.*

By the Rev. D. WILLIAMS, F.G.S.

[Read June 10th, 1840.]

I FEEL much pleasure in announcing to the Society, that a cutting for the Bristol and Exeter railway through the extreme western termination of Bleadon Hill has within these few days disclosed a mass of fine porphyritic trap, the first instance hitherto observed of the occurrence of an igneous rock in the Mendip Hills, or within the area of the Bristol coal-field. The trap varies from a granular greenstone with hornblende to a compact porphyritic rock, inclosing amygdaloidal kernels of calcareous spar and brown hematite; other specimens exhibit crystals of glassy felspar, and the rock is sometimes laminated and friable. The bed of mountain limestone which rests immediately on the trap differs in colour, and is much more brittle than the other strata.

Rare as such igneous products are in this region, they are scarcely less so throughout the whole of Exmoor and the Quantocks; for, except the syenitic granite and trappean porphyry of Hestercomb in the Quantocks, first noticed by Mr. Horner*, a slaty porphyry I met with a little north of Simmons-birth in Exmoor, and the elvan blocks near Morte Point, mentioned by Mr. De la Beche†, all associated with the same slate series (No. 5. of my subdivision), which rests on the granite of Lundy Island, I know of none. The next nearest igneous rocks are those about Tortworth in Gloucestershire, in the Caradoc sandstone division of the Silurian system of Mr. Murchison.

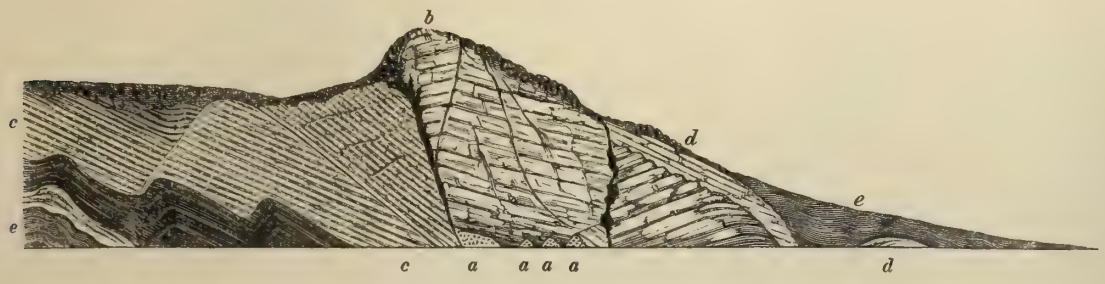
The cutting for the railway intersects the broadest part of the ridge of lias and new red sandstone, which I formerly pointed out‡ as filling up a great interval or original gorge between the limestone of Bleadon and Uphill.

* Geol. Trans., First Series, vol. iii. p. 348, 1816.

† Report, Geology of Cornwall and Devon, pp. 49, 186, 1839.

‡ Geol. Proceedings, vol. ii. p. 79, 1833.

For the principal details represented in the accompanying woodcut I am indebted to Mr. Peniston the resident engineer, who had the kindness to prepare for me a graphic representation of the whole cutting, but of which only a portion is here given.



a, Trap, apparently substituted for the originally continuous limestone, by slow fusion and conversion.
b, Mountain limestone, showing remarkably uneven surfaces and ragged edges at its immediate contact with the trap.
c, Blue lias, overlying black shales with the Watchet and Aust Cliff bone-bed; grey passage marls below.
d, Dolomitic limestone, resting unconformably on the successively outcropping steps of the mountain limestone.
e, Upper gypseous red marls of the new red sandstone.

XXXVI.—*Notices from the Minute Books of the Geological Society.*

1. *On the Geological Structure and Phænomena of the Northern Part of the Cotentin, and particularly in the immediate vicinity of Cherbourg. By the* Rev. W. B. Clarke, A.M., F.G.S., &c. (Read Feb. 1, 1837.)

THE author commences by stating, that no fact among the geological phænomena presented in both hemispheres, appears to be more clearly determined than the occurrence of granitic rocks of posterior date to deposits containing organic remains of comparatively recent origin. Instances of this position, he says, are exhibited on a great scale in Brittany, Normandy, and the Channel Islands, where quartz rock and schists (the last containing, as will be subsequently shown, vegetable and testaceous remains) have been disturbed by granite and the protrusion of the latter effected by trap; and he refers to Humboldt's allusion to the Cotentin in proof of the intimate connexion of quartz rock, schist (occasionally connected with limestone), and granite*; also to the memoir of M. Alex. Brongniart on the Cotentin †, with the note by M. d'Omalius d'Halloy on Brittany ‡; likewise to Mr. De la Beche's paper on Calvados and La Manche §; as well as the memoirs of Professor Sedgwick and Mr. Murchison on Cornwall and Devonshire ‖, &c., for the occurrence of the same series of rocks under precisely similar conditions in each district ¶, and for evidences that the granite was protruded at a comparatively recent period, not only altering the characters of the associated sedimentary strata, but elevating the rocks *en masse* to their present positions. With respect to the phænomena exhibited in the Channel Islands, Mr. Clarke says, that the granitic, schistose and quartz rocks are exactly in the range of the analogous formations of the Cotentin; that the trap of Sercq occurs intermediate to the other deposits, as in the Cotentin; and that to the protrusion of the trap the actual position of the granite, slates and quartz rock must be assigned.

* 'Sur le Gisement des Roches,' pp. 106, 145, 1823.

† Journal des Mines, tome xxxv. p. 109 *et seq.*, 1814.

‡ *Ibid.*, p. 112, note 2.

§ Geol. Trans., Second Series, vol. i. p. 73 *et seq.*, 1822.

‖ Prof. Sedgwick, on the Structure of large Mineral Masses, Geol. Trans., Second Series, vol. iii. p. 484 *et seq.* Prof. Sedgwick and Mr. Murchison on Devonshire, Report of the British Association for 1836.

¶ For instances out of Europe, reference is made to Capt. Burne's remarks on Hindoo Kosh, Geol. Trans., vol. iii. p. 492; and Humboldt's 'Gisement des Roches,' pp. 103 *et seq.*, p. 143 *et seq.*

Mr. Clarke then describes in some detail the country in the immediate vicinity of Cherbourg, following closely M. Alex. Brongniart's account of the physical features and lithological structure of the country.

The district consists of a succession of lofty ranges composed of quartz rock, and of valleys with low hillocks of schists ; and masses of granite and trap occasionally protrude through the other deposits.

The schists vary in composition, being sometimes argillaceous, sometimes talcose, also in hardness and colour. At Vasterville, to the S.E. of Cherbourg, beds of grey slate and graphite ampelite contain impressions of marine plants ; and at Barneville, to the south of Les Pieux, calcareous strata alternating with schist inclose Terebratulæ. One variety of slate, called by M. Brongniart *stéaschiste noduleux*, consists of a base of green glossy slate, with egg-shaped nodules of quartz, and passes into talc slate, which also contains concretions of felspar and crystalline quartz of very variable size and form, and occasionally penetrated by the talcose matrix.

The quartz rock assumes also very different degrees of hardness, and changes often in its lithological aspect. Near Vasterville it puts on the character of a ferruginous sandstone and passes into a conglomerate ; and though these varieties are stated, on the authority of M. d'Halloy, to be of frequent occurrence, yet Mr. Clarke is of opinion that the ferruginous nature of the rock must be considered as adventitious and of subsequent origin, being impressed also upon the schist. The apparent arenaceous structure of certain beds at Le Roule is stated to disappear under the lens, the whole mass presenting a vitreous fracture. The strata are generally inclined at a considerable angle, but the direction of the dip varies ; they are also occasionally curved. The prevailing strike of both the quartz rock and the schist is from east to west. Insensible gradations from one formation to the other are prevalent ; and at Rozel green schist is succeeded by quartz rock, and felspar trap passes into schistose greenstone ; at Flamanville the latter rock also alternates with compact eurite, which changes into rosy syenite, alternating with trap, and is succeeded by regularly stratified beds of syenite, having the same direction with those of the quartz rock*. Mr. Clarke gives many other local details, either on his own authority or that of M. Brongniart ; and then offers the following general summary of the changes at the lines of junction. The argillaceous and talcose schists, where they are in contact with the quartz rock, partake of a gradual intermixture of the components of that formation, and the same strata in contact with granitic rocks become charged with particles of felspar.

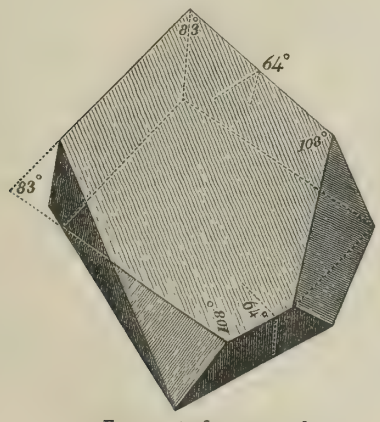
That the original phænomena took place whilst the slate was still soft and in the bed of the ocean, Mr. Clarke says, there can be no reasonable doubt ; but he is of

* See M. Brongniart's Mém., Journ. des Mines, t. xxxv. p. 119.

opinion that the physical outline of the country indicates considerable changes incident to the emergence of the land. The deep transverse valley which intersects the mountain called Le Roule, a little to the east of Cherbourg, is stated to present some interesting phænomena. The eastern escarpment, from 300 to 320 feet in perpendicular height, slopes gently to the south as far as the commencement of the slate, where the descent becomes extremely rapid into the valley of the Divett. The western side of the ravine presents similar features, but in a reversed position; the escarpment of quartz rock, crowned by the Telegraph, being to the south, and the slope to the north, with a very gentle inclination till it reaches the sea-level. These opposite interchanges of slope and escarpment are occasioned, Mr. Clarke says, by the direction and prolongation of the beds of slate, the line of coast not exactly corresponding with the junction of the schist and quartz rock. The southern junction of the two formations is about half-way up the ravine, near a chapel; and in the quarries along a road leading eastward, the phænomena exhibited at the contact of the deposits are well-exhibited. Throughout the district the range of the slate is marked by the fertility of the soil and the occurrence of woods, but that of the quartz-rock by a prevailing barrenness.

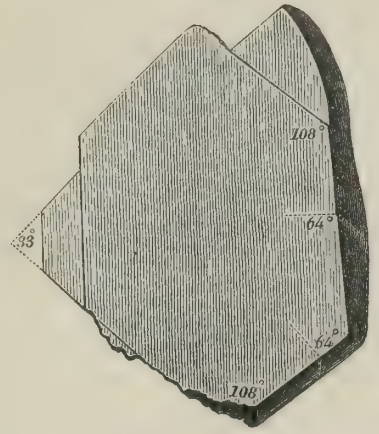
Fragments of the latter formation are either scattered over the surface, associated with clay, or compose mounds free from extraneous matter; and they preserve the characteristic form of the parent rock, the angles, measured "by a goniometer," affording three constant quantities, namely 108°, 64°, and 83° (fig. 1.); and the last angle measures also that formed by the production of two sides, which in the actual specimens are cut off by the intersection of a third plane. Fragments of green schist detached by the hammer at the natural joints, gave also the same angles, or 108°, 64°, and 83° (fig. 2.); so that there is direct evidence, Mr. Clarke observes, of the

Fig. 1.



Fragment of quartz-rock.

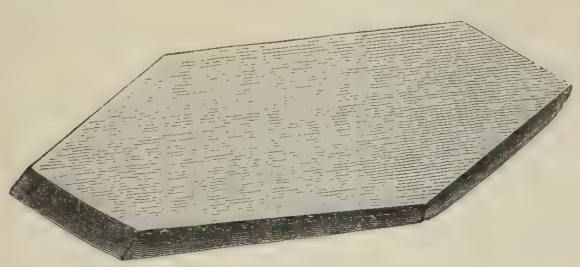
Fig. 2.



Fragment of green schist.

same agent having operated on both formations *en masse.* The rock of Le Roule presents to the eye two lines of fracture, one parallel to the horizon and the other nearly perpendicular to it, and these, with the lines of dip and direction, produce, the author says, the peculiar outline of the fragments. This structure, Mr. Clarke considers, is due to the arrangement of the component particles in the first instance, and to subsequent agents in the second; and he is of opinion the phænomena prove distinctly the truth of Brongniart's assumption, that these are crystalline and not mechanical rocks. If, he adds, heat was an agent in consolidating these beds, and electrical action was connected with it, the tendency of the strata to assume their characteristic features might be accounted for. Other cases of slates assuming a regular form are mentioned in the paper, particularly one at Boppart, on the Rhine, where the cleavage yielded six-sided tables, somewhat similar to the fragments previously mentioned. (Fig. 3.)

Fig. 3.



Fragment of slate from Boppart, on the Rhine.

The transverse ravine of Le Roule is shown to agree precisely with the strike of veins of pure white quartz, which intersect the strata from south-east to north-west; and Mr. Clarke observes, that this direction of the ravine corresponds with the *mechanical* effect of elevation; and he dwells at some length on this not being a local phænomenon, but connected with a widely extended operation. The transverse break through the beds of hard chalk at Corfe Castle, on the coast of Dorsetshire, is considered as probably connected with the ravine at Cherbourg; and he proceeds to state, that if the observer extend his researches to Calvados and Brittany, and thence to Devonshire, Weymouth, Purbeck, the Isle of Wight, the Weald of Sussex and Kent, and the Boulonnais, he would be induced to connect some of the most striking phænomena of these districts with probably a contemporaneous series of events.

The decided similarity of the Devonshire schists and granite with those of the French coast; the similar protrusion of the granite at an epoch much posterior to the production of the slates; the occurrence of highly inclined beds from the oolites to the tertiary series along the coast of Dorset, dipping, like the rocks of the Co-

tentin, to the north; the existence of a series of faults in Dorset ranging in a linear direction with the elevated beds of the Cotentin, as well as another transverse series on the coasts of England and France, are conditions which appear to agree so accurately under all their bearings, as to induce, the author says, the supposition, that the tract now occupied by the English Channel between Cape La Hogue and Portland owes its existence to a denudation of deposits intermediate between the slate and the oolites, in the direction of the similar but minor valleys in La Manche; and that the appearances of elevation so extensively developed on both sides of the Channel owe their origin to one common, deep-seated cause, evidence of which is afforded in the traps and granites of La Manche, Brittany, Devonshire, Cornwall, and the Channel Islands. Lastly, with reference to the belief which had been entertained by a previous observer, that the western coast of the Cotentin may have originated in a fracture, Mr. Clarke observes, that there is reason to infer that the coast-lines, not only of the Cotentin, but of the Channel Islands, Purbeck and the Isle of Wight, will be found to have been produced by a series of contemporaneous or successive upheavings of the strata in the same linear direction, at an epoch posterior to the formation of the tertiary deposits.

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2. *Extract from a Letter dated Marciana, Elba, Sept.* 1, 1837, *addressed to the Rev. William Buckland, D.D., V.P.G.S. By* Walter Calverly Trevelyan, *Esq., F.G.S.* (Read Nov. 15, 1837.)

"On the shore near the point where the road descends towards the rock or islet of Lihou, on the east of Guernsey, may be seen a section, in which, above the present high-water mark, the granite rock bears evident signs of having been worn by the action of the waves, previously to the deposition on it of a bed of gravel, which now covers the granite and fills up the inequalities of its surface. The gravel, which is firmly bound together by a ferruginous sand, consists of pebbles of the neighbouring rocks, also of chalk flints, some not much rounded; and it extends to about eight feet above the present high-water mark, ranging also apparently a little inland. On the gravel is a bed, about three feet thick, of disintegrated granite, mixed with angular fragments of that rock and covered by the surface soil."

On the north-west side of the island, near Fort Doyle, a similar gravel occurs, about eight feet above high-water mark, resting principally on the surface of the syenite rocks of a low cliff, but occupying also fissures, which Mr. Trevelyan is of opinion, were formed during a slight elevatory movement, and into which he be-

lieves the gravel fell, and was even forced laterally under the syenite (see fig. 1. and 2.). In fig. 2. a small horizontal fissure, A, resembling a vein, and about half

Fig. 1.

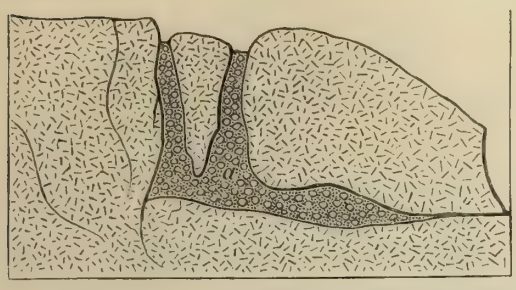
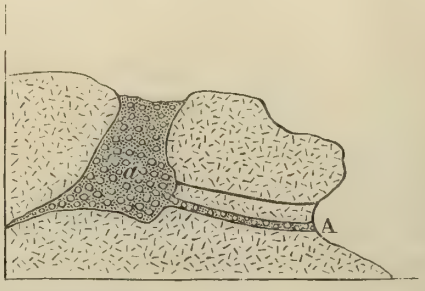


Fig. 2.



Gravel (*a*) occupying vertical and horizontal fissures in syenite.

an inch wide, extends beneath the apparently unmoved rock. This layer also contained some small flint pebbles. The gravel is in parts so firmly cemented by a ferruginous sand, as to be able to support the roof of a small cavern, where the substratum had been washed away.

These observations were made in the year 1833, and when Mr. Trevelyan re-examined the locality in 1835, he saw no reason to change the opinion he formed during his first visit.

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3. *On the Illustration of Geological Phænomena by means of Models. By* T. Sopwith, *Esq., F.G.S.* [The notice which accompanied the models was read.]

The models which accompanied this communication are designed to illustrate the nature of stratification, valleys of denudation, the succession of coal-seams in the Newcastle coal-field, and the effects produced by faults or dislocations of the strata* ; and the author states that his object in constructing them is to meet the impossibility of representing by ordinary drawings more than one plane without a certain amount of distortion, and to explain the totally different phænomena which the strata beneath a given area may exhibit from those which are exposed on the surface. In order to accomplish fully the latter intention, several of the models are composed of moveable pieces, and by detaching one or more of these the effects of dislocations are made apparent, and the real value of a mineral district so circumstanced rendered perfectly clear.

The models are twelve in number.

1. The first represents a district consisting of horizontal strata, and the upper

* See Mr. Sopwith's work, entitled "Description of a series of Geological Models;" 12mo, 1841.

surface exhibits a plane composed of one description of deposit. By detaching the moveable part, a valley of denudation is exposed, and in consequence of a slight inclination being given to the valley, the difference in the stratification which a series of horizontal beds may exhibit at the extremities of a valley is clearly shown.

2. Number 2. represents a portion of the Newcastle coal-field. The top exhibits an undulating surface, and the outcrop of a coal-seam, once apparently coextensive with the whole area of the district, but now limited, owing to denudation, to its highest part. In the lowest portion of one of the valleys, the outcrop of another seam is exposed for a short distance. The mode of working a bed of coal is shown by removing the upper portion of the model.

3. Number 3. exhibits one side of a valley of denudation. The strata appear to be horizontal, and in their original relative position, but by referring to the sides of the model a certain amount of displacement is shown; and the effects of a still greater dislocation may be exhibited by removing the under portion of the fore-part of the model, and placing in the position it occupied, the piece which rested on it: by withdrawing the other upper portion, one side of a valley of denudation is again displayed, and though the amount of dislocation is great, only a simple alternation of similar beds is visible on the surface.

4. The next model illustrates the errors which might be committed in estimating the number of coal-seams in a district by surface indications. Along the two inclined ridges there are apparently five beds of coal alternating regularly with the usual measures; and it is only by endeavouring to follow them across the valley of denudation, and laterally beyond the ridges, that the true characters of the district can be discovered. The seams are then found to terminate abruptly, and the observer would infer first, that the coal-measures are affected by faults; and afterwards, from a series of careful researches, aided by borings, that there are in reality but three distinct seams,—the two which crop out around the culminating ridge, and another, which underlies, and is visible only in the lower portions of the valley of denudation, where it is twice exposed. The great amount of dislocation thus ascertained would lead the practical miner to abandon a district apparently of great value. An oblique intersection of the model illustrates the complications produced in the interior of such a district, the vertical sides show the number of faults as well as the amount of dislocation attending each; and the true stratigraphical structure is exhibited by the back.

5. In the last model the denudation is at right angles to the direction of the strata, and consequently exposes the apparent vertical succession of beds; but in this it is parallel to their direction, and therefore has laid bare only a limited amount of strata. No coal-seams are visible, nor any indications of the subjacent mineral

wealth, except that the sandstones and shales displayed on the surface belong to the carboniferous measures. That the district is affected by faults, may be inferred from the repetition of beds identical in mineral character, and the amount of the presumed dislocations may be easily ascertained. In this instance the value of the seams of coal, which trials may have proved, is less affected than in No. 4, and the probable produce, in the direction of the strike, may be estimated. The depth at which the same bed may be found between the lines of fault is also readily determined, and the working of the coal resumed, should the calculated produce justify the undertaking. The true nature of the district is exposed on the sides of the model, and the complication of the interior, in a plane oblique to the horizon, is shown by removing the upper part.

6. This model exhibits some of the phænomena of the intersection of veins; also the different relative levels of the surface of a dislocated bed of coal. Mr. Sopwith, in his description of the models, considers the white vein as marking the first dislocation, whereby the relative displacement of 4 and 3 with reference to 1 and 2 was effected; 2 by that movement not having been detached from 1, but continued on the same level, nor 3 from 4; and it will be easily perceived that if 2 and 1 be, in imagination, placed on the same plane, 3 and 4 will likewise constitute a continuous plane at a certain lower level: by a subsequent dislocation, marked by the brown vein, 1 and 4 are supposed to have been upcast, or 2 and 3 thrown down, 1 and 4 preserving their former relative positions as well as 2 and 3. Two dislocations therefore produced 4 different levels. In consequence of the intersecting cracks or veins not being perpendicular to the horizon, there is an apparent lateral shift at the point of intersection, not only in the veins, but in the portions 2 and 3 of the coal-bed. The phænomena dependent on the structure of the model are exhibited as usual by the sides and by an oblique intersection, and Mr. Sopwith points out the means by which the relative antiquity of intersecting veins may be determined.

7. In this model the effects of denudation on No. 5. are shown, the angular irregularities produced by the dislocations being rounded off, and the physical outline giving no indication of the disturbances. On a comparison of the two models, the same description of displaced plans will be found in each. In No. 7, Mr. Sopwith has introduced a groove which traverses the upper part of the model, and is supposed to represent the boundary of an estate. By referring to the back of the model, it will be perceived that the groove is carried down perpendicularly, defining underground the limits of two estates; it will also be perceived that the white vein is intersected by it, and consequently the right of working the vein possessed by the owner of the property in which it appears on the surface would cease at the line of intersection.

8 and 9. These models exhibit the effects of denudation on strata differently inclined, and the inferences which may be deduced respecting the dip of the beds, by attending to the position of the re-entering angle of the strata in transverse valleys of denudation. In No. 8. this angle is pointed up the valley, the strata having been "overcut" or acted upon, nearly in the direction of their dip: in No. 9. the re-entering or V angle points down the valley, in consequence of the greater inclination of the strata and the denuding force having acted obliquely to the dip, and "undercut" the beds or denuded first the lowest, constituting the crest of the hill. In the case exhibited in model No. 8, the observer in ascending the valley passes regularly from the lowest to the highest strata; but in the instance represented by No. 9, the highest strata form the lowest part of the valley, and in ascending its course a succession of underlying beds are passed over. Without due attention, however, to the direction of the V angle, the reverse might be inferred, and the strata might be considered to dip into the rising ground, and not obliquely from it. Many points of great interest connected with mining, and dependent upon the direction of the V angle, are pointed out by Mr. Sopwith.

10. This model exhibits the effects of denudation on the outcrop of strata, the direction of the dip being into the hill or rising ground, and not, as in the two last cases, more or less parallel with it. In this instance the V angle appears to point up the valley, but by tracing the outcrop it is found to incline *into* it, the beds forming the V occupying a higher level on the flanks than in the bottom of the denudation.

11. The object of this model is to exhibit the effects produced by the intersection of veins on a vertical surface, on an inclined plane, and on a horizontal one (the bottom of the model). The white vein is also shown to be of greater antiquity than the red, having been dislocated by it.

12. The last model explains the effects of denudation on a mineral district identical in structure and the amount of disturbance with No. 11.

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	Mineralogische u. bergmännische Abhandlungen, herausgegeben von Joh. C. W. Voigt, Zweyter Theil. 12mo. Leipzig, 1789.	.....
	Kleine Mineralogische Schriften, von Joh. C. W. Voigt, Erster Theil. 12mo. Weimar, 1799.	.....
	Drey Briefe über die Gebirgs-Lehre für Anfänger und Unkundige, von Joh. C. W. Voigt. 12mo. Weimar, 1786.	.....
	Die Vulkane älterer und neuerer Zeiten, von Franz von Beroldingen. 8vo. Mannheim, 1791.	.....
	Geschichte und Systematische Beschreibung der in der Grafschaft Hanau Münzenberg, in dem Amte Bieber und andern Aemtern dieser Grafschaft, auch den dieser Grafftschaft benachbarten Ländern gelegen Bergwerke, von Franz Ludwig von Cancrin. 12mo. Leipzig, 1787.	.....
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A Familiar Discourse or Dialogue concerning the Mine-Adventure, 8vo. London, 1700.	.....
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Dei Vulcani o Monti Ignivomi piu noti, e distintamente del Vesuvio osservazioni Fisiche e Notizie Istoriche di Uomini Insigni di vari tempi, racolte con diligenza. 2 vols. 12mo. Livorno, 1779.	.....
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The London and Edinburgh Philosophical Magazine and Journal of Science, conducted by Sir David Brewster, K.C.H., LL.D., F.R.S. L. and E., &c., Richard Taylor, Esq., F.S.A., L.S., G.S., &c., and Richard Phillips, Esq., F.R.S. L. and E., F.G.S., &c. July 1840 to June 1841. 8vo. London.	Richard Taylor, Esq., F.G.S.
The Repertory of Patent Inventions, and other Discoveries and Improvements in Arts, Manufactures, and Agriculture, July 1840 to June 1841. 8vo. London.	The Proprietor.
The Magazine of Natural History, new series, conducted by Edward Charlesworth, F.G.S., &c., July to August 1840. 8vo. London.	The Conductor.
The Athenæum Journal of English and Foreign Literature, June 1840 to May 1841. 4to. London.	The Editor.
The Microscopic Journal and Monthly Record of Facts in Microscopical Science, edited by Daniel Cooper, M.R.C.L., vol. 1, nos. 1 to 5. 8vo. London, 1841.	The Microscopical Society.

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Proceedings of the American Philosophical Society, vol. 2. No. 17. 8vo.	.....
Résumé des Observations sur la Météorologie, sur le Magnétisme, sur les Températures de la Terre, sur la Floraison des Plantes, &c., par A. Quetelet. 4to. (Extrait du Tome 14 des Mémoires de l'Académie Royale de Bruxelles.) 1841.	The Author.
Nouveaux Mémoires de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles, tome 13. 4to. Bruxelles.	The Royal Academy of Sciences of Bruxelles.
Mémoires Couronnés par l'Académie Royale des Sciences et Belles Lettres de Bruxelles, tome 14. Deuxième partie, 1839–1840. 4to. Bruxelles.	.....
Des Moyens de soustraire l'Exploitation des Mines de Houille aux chances d'Explosion. Recueil de Mémoires et de Rapports publié par l'Académie Royale des Sciences et Belles-Lettres de Bruxelles. 8vo. Bruxelles, 1840.	.....
Bulletins de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles, Année 1840. Tome 7, partie 1re et 2me. 8vo. Bruxelles.	.....
Annuaire de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles. Septième Année. 18mo. Bruxelles, 1841.	.....
July 16. Transactions of the Zoological Society of London, vol. 2. part 5. 4to. London.	The Zoological Society of London.
List of papers contained in vol. 2 of the Transactions of the Zoological Society of London.	.....
Proceedings of the Zoological Society of London, January to September 1840. 8vo.	.....

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July 23. Proceedings of the Royal Society of London, nos. 45 to 48, 1841. 8vo.	The Royal Society.
Essai sur la Statistique Générale de la Belgique, composé sur des Documents publics et particulièrs; par Xavier Heuschling, et publié par Ph. Vandermaelen. Deuxième Edition. 8vo. Bruxelles, 1841.	M. M. Ph. Vandermaelen, F.G.S.
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Bulletin de la Société Géologique de France, tome 12. feuilles 18–21. 8vo. Paris.	Geological Society of France.
Det Kongelige Danske Videnskabernes Selskabs Naturvidenskabelige og Mathematiske Afhandlinger. Ottende Deel. Med. 33 Tavler. 4to. Kjöbenhavn, 1841.	Royal Society of Copenhagen.
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Proceedings of the Committee of Commerce and Agriculture of the Royal Asiatic Society of Great Britain and Ireland. 1841. 8vo. London, 1841.	.....
Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset, by John Phillips, F.R.S., G.S., &c. 8vo. London, 1841.	The Author.
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Sept. 15. Eighth Annual Report of the Royal Cornwall Polytechnic Society, 1840. 8vo. Falmouth, 1840.	Royal Cornwall Polytechnic Society.
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Sept. 17. Philosophical Transactions of the Royal Society of London, part 1, 1841. 4to. London, 1841.	The Royal Society.
Bulletin de la Société Géologique de France, tome 12, feuilles 22–27. 8vo. Paris.	Geological Society of France.
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Sept. 22. Transactions of the Linnean Society of London, vol. 18, part 4. 4to. London, 1841.	Linnean Society of London.
Proceedings of the Linnean Society of London, from April 7th, 1840, to June 1, 1841. 8vo.	.....
List of the Linnean Society of London for 1841. 4to. London, 1841.	.....
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Bericht über die zur Bekanntmachung geeigneten Verhandlungen der Königl. Preuss. Akademie der Wissenschaften zu Berlin. (July 1840 to June 1841.) 8vo. Berlin, 1840–1841.	.....
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The American Journal of Science and Arts, conducted by Prof. Silliman, M.D., LL.D. vol. 41. July and October, 1841. 8vo. New Haven, 1841.	The Conductor.
Transactions of the Cambridge Philosophical Society, vol. 7, part 2. 4to. Cambridge, 1841.	Cambridge Philosophical Society.
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Brevi Cenni sullo Studio della Zoologia Fossile per L'Avv. G. Michelotti. 8vo. Torino, 1841.	The Author.
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Sur le Système Silurien de l'Esthonie, par Dr. Eichwald. 8vo. St. Petersbourg, 1840.	The Author.
Ueber Ichthyosauren und Ceratiten Russlands, von Dr. Eichwald. 8vo. 1841. 2 copies.	The Author.
The Natural History of the Earth, Illustrated, Inlarged, and Defended, by John Woodward, M.D. 8vo. London, 1726.	John Wiggins, Esq., F.G.S.
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Mémoires Couronnés par l'Académie Royale des Sciences et Belles-Lettres de Bruxelles, tome 15, 1re partie 1840–1841. 4to. Bruxelles, 1841.	.....
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	Erdkunde. (Geologie) Ein Versuch den Ursprung der Erde und ihre allmählige Umänderung bis aus den heutigen Tag mit naturwissenschaftlicher Nothwendigkeit aus der Nebelhypothese des La Place zu folgern, von Dr. A. Petzholdt. 8vo. Leipzig, 1840.	The Author.
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Graptolites from Ireland.	Capt. Portlock, F.G.S.
Fossils from the Mountain Limestone, Ireland.	W. J. Henwood, Esq., F.G.S.
May 30. Crystals of Greenockite from near Bishopton, Renfrewshire.	Lieut.-Gen. Lord Greenock, F.G.S.
June 1. Geological Specimens from Jersey.	H. C. White, Esq., F.G.S.
Casts from Specimens of Sandstone discovered at Bajntz in Transylvania, and of the Footsteps of *Testudo Mydas.*	Rev. Prof. Buckland, D.D., F.G.S.
Specimen of *Stromatopora concentrica.*	W. V. Guise, Esq., F.G.S.
Fossils from the Greensand of Farringdon, and the Great Oolite of Cain's Cross, Gloucestershire; and specimens of *Apiocrinites rotundus.*	Miss Benett, of Norton House.
Crania from the Chalk of the Baltic.	Rev. W. Bilton, F.G.S.
Specimen of Lithodendron from Lough Gill, County Sligo.	Earl of Enniskillen, F.G.S.
June 29. Specimens of Anthracite and Bituminous Coals; Iron, Copper, and Lead Ores; Fluviatile Shells., &c., from Pennsylvania and Cuba.	R. C. Taylor, Esq., F.G.S.
Specimens from the Inferior Oolite, Leckhampton Hill, &c.	W. V. Guise, Esq., F.G.S.

IV. *Miscellaneous.*

Aug. Model, coloured Geologically, of part of the Swiss Jura, by M. Gressly.	Prof. Agassiz, For. Mem. G.S.

PLATES AND MAPS

IN ILLUSTRATION

OF

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EXPLANATION OF THE PLATES AND WOODCUTS.

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It has been deemed advisable to reproduce these figures in order to dissipate the doubts which have been expressed* as to whether this upper jaw actually belonged, as Cuvier believed, to the same animal as the fragment of the lower jaw figured by Cuvier.

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The outline figure represents the jaw of the natural size.

Fig. 2. The corresponding view of the left ramus of the lower jaw of the *Myrmecobius fasciatus,* Waterhouse.

The outline figure represents the jaw of the natural size.

Fig. 3. Inside view of the left ramus of the lower jaw of the *Thylacotherium Prevostii,* Val.

The outline figure represents the jaw of the natural size.

It is the original Stonesfield fossil examined by Cuvier, and figured by M. Prevost, 'Annales des Sciences Nat.,' Avril 1825, pl. xviii., and by Dr. Buckland, 'Bridgewater Treatise,' ii. pl. ii. fig. B.

In each figure *a* indicates the condyle or condyloid process; *b,* the coronoid process; *c,* the angle or angular process; *d,* the inferior longitudinal groove; *e,* the symphysis of the jaw.

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Fig. 1. Inside view of the left ramus of the lower jaw of the *Thylacotherium Broderipii.*

The outline figure represents the jaw of the natural size.

* See the 'Palæologicæ' of H. von Meyer, p. 53.

This figure is taken from the specimen presented by the Rev. H. Sykes to the Museum of the Philosophical Institution of York, where it is now preserved. The opportunity of describing and figuring this interesting specimen was afforded me, subsequently to the communication of the papers on the *Thylacotherium Prevostii* and *Phascolotherium Bucklandi* (pp. 45 and 57), by my friend Prof. Phillips, to whom I beg to return my best acknowledgments. This specimen, which, like the others, is from the oolitic slate of Stonesfield, is more perfect in regard to the teeth than either of the above-described jaws of the smaller species of *Thylacotherium*. That it belongs to this genus is proved by the number of teeth, and there is a close correspondence in the form of the jaw; but the difference of size is greater than has been observed in mature individuals of the same species of Placental or Marsupial Insectivores. I therefore indicate the species which this fossil represents under the name of *Thylacotherium Broderipii*, in honour of the geologist and naturalist to whom we are indebted for the first description and figure of the Stonesfield mammiferous remains.

In this, as in the two preceding instances, it is the left ramus of the lower jaw which offers its inner surface to the observer: it presents at its anterior part the sockets of three incisors and one canine, of small and nearly equal size, each having a simple fang; then follow the empty sockets of three small false molars, each with two fangs; to these succeed three large false molars, in place, each having two fangs protruded to a certain extent from their sockets, and fixed by the adherent matrix in that position, which proves that they were not anchylosed to the osseous substance: these teeth became loosened and displaced doubtless after decomposition of the soft parts; and the anterior teeth, which are missing, were probably lost from the same cause, before the jaw was finally encased in the oolite. There is a small anterior as well as posterior tubercle at the base of the large middle cusp or cone, in each of the three premolars which are in place: the middle cusp of the posterior one is fractured: there is a slight ridge along the inner side of its base in that tooth, indicating the transition to the true molar series. The first true molar is wanting; the next four present the inner surface of their crowns in a perfect and uninjured state: the large middle cusp has a smaller one at the anterior and posterior part of its base; this is traversed by a strong ridge along the inner side, which supports three small cusps; one of these rises at the middle of the base of the large external cusp, and the other two form the anterior and posterior extremities of the crown of the tooth. This form of grinder resembles that of the *Phascolotherium*, except in the presence of the middle internal cusp, more than that of the molars of the true *Didelphys*. The condyloid and coronoid processes have both left their impressions on the matrix: the angle of the jaw is fractured: there is the same shallow, wide and smooth groove near the lower margin of the jaw, and the same notch in the symphysis.

Fig. 2. Inside view of the right ramus of the lower jaw of *Phascolotherium Bucklandi*; from the specimen in the British Museum. *Didelphys Bucklandi*: Broderip, 'Zoological Journal,' vol. iii. p. 408, pl. xi.; Buckland's 'Bridgewater Treatise,' pl. ii. A.

The outline figure represents the jaw of the natural size.

In both the figures *a* indicates the condyle; *b*, the coronoid process; *c*, the angular process of the jaw; *d*, the inferior longitudinal groove.

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Fig. 5*a*. Anterior view of a corresponding vertebra of the *Python tigris*.

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The same letters indicate the same parts in each figure.

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All the figures are of the natural size.

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Fig. 10. Relative positions of the Devonian and Silurian strata at Sötenich, in the district of the Eifel: p. 267 *et seq.*

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Fig. 12. General section of the Ardennes, to show the relations of the Eifel on one flank and of the Liège country on the other to a central axis of older slaty rocks.

The youngest deposit in the Eifel is the equivalent of the South Devon limestone, and it passes into Silurian greywacke. On the Belgian side of the Ardennes the strata are frequently inverted, as pointed out by M. Dumont in his work on the province of Liège, and as represented in this section, fig. 12: p. 261 and p. 267 *et seq.*

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Figs. 15. and 16. These sections represent the structure of the country south of the Fichtelgebirge in Upper Franconia: p. 298 *et seq.*

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The second section (fig. 16.) shows that the limestones of Elbersreuth and Schubelhammer (so celebrated for their organic remains) are members of the Devonian system, but affected by eruptions of trap, and greatly dislocated: p. 300.

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the authors; and the map is chiefly intended to indicate approximately the relations of the great subdivisions of the older sedimentary deposits: p. 227 *et seq.*

PLATES XXV. to XXXVIII.

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WOODCUTS.

Fig. 1. Section near Arnsberg in Westphalia. An axis of carboniferous black limestone and Kiesel-schiefer, representatives of the culm limestone and flinty slate of Devonshire, is shown to be succeeded on each flank by the lower unproductive coal-measures, undistinguishable from those of Bideford: p. 233.

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Fig. 11. A species of *Homalonotus* resembling *H. Knightii*: p. 275.

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Fig. 13. Section of the celebrated fossiliferous strata of Gerolstein, and of their dislocations. The organic remains are, for the most part, procured from the bands of limestone and shale between the dolomite and the Silurian flagstones with Homalonoti: p. 278.

Figs. 14 and 15. Sections in the Hartz: p. 286.

Fig. 14. Inverted and fragmentary condition of Devonian and Silurian strata near Goslar, north of the Brocken: p. 286.

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Fig. 16. Section of the slate quarries of Nordberg near Goslar. In this cut are represented the independence of bedding, cleavage and joints. The undulating lines indicate the bedding, the oblique the cleavage, and the horizontal the peculiar joints or floors. At the junction with the flanking masses of trap the slate is much altered: p 290.

PLATES XXV. to XXXVII.

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Fig. 5. Coast-section near Dawlish, exhibiting the faults in the new red sandstone: pp. 483, 486.

Fig. 6. Section of the unconformable position of the carbonaceous deposits to the lower rocks near Chudleigh; and of the intrusive trap: pp. 458, 460, 472.

Fig. 7. Road-section near Newton: p. 463.

Fig. 8 A to 8 E. Sections to explain the relative positions of the carbonaceous shale and limestone between Oxencombe and Chudleigh Bridge: p. 461.

Fig. 9. Section near Knowle, exhibiting contorted bands of limestone in slate: p. 488.

WOODCUTS.

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Fig. 4. Section of recent marine deposits, presenting instances of oblique lamination: p. 442.

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Fig. 13. Ground plan of a trap dyke intersecting slates near West Down: p. 471.

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WOODCUT.

Map of the Peninsula Aden, to illustrate Mr. Burr's account of the volcanic phænomena and rocks of the district: p. 499.

WOODCUTS

To illustrate Mr. Owen's memoir on the teeth of the *Labyrinthodon*: p. 503—513.

Fig. 1. Part of a transverse slice of the tooth of *Labyrinthodon Jægeri*, as seen by transmitted light; magnified 10 diameters: p. 506.

Fig. 2. Portion of a transverse slice of the tooth of a *Labyrinthodon* from the Warwick sandstone: p. 511.

PLATES XLIII. to XLVII.

Illustrate Mr. Owen's paper on parts of the skeleton and teeth of five species of *Labyrinthodon*: p. 515.

Plate XLIII.

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Fig. 2. The same, seen from below: p. 517–521.

a, Large anterior tusk of the outer dental series: p. 517.

b, Left vomerine bone, supporting the inner series of teeth: p. 519.

c, Posterior palatal foramen: p. 520.

d, Part of anterior dental foramen: p. 520, 521.

Fig. 3. Side view of the same fossil: p. 516–521.

a, Large anterior tusk of the outer dental series.

b, Ditto ditto inner or vomerine series.

c, Bony palate forming the floor of the nasal cavity.

d, Roof of nasal cavity.

e, The nasal cavity, filled with matrix.

Fig. 4. Portion of left upper jaw of *Labyrinthodon pachygnathus*: p. 528.

Fig. 5. A smaller fragment of the same.

Fig. 6. Serial teeth of the *Labyrinthodon pachygnathus*.

Figs. 7. and 8. Two views of a portion of the lower jaw of *Labyrinthodon pachygnathus*.

Fig. 9. Portion of the upper jaw of *Labyrinthodon pachygnathus*: p. 529–530.

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b, Outer palatal plate of the same bone: p. 530.

c, Inner palatal plate, forming the anterior palatal foramen.

Fig. 10. Side-view of the same fossil: p. 529–530.

c, Anterior palatal foramen.

d, Maxillary or upper wall of nasal cavity.

e, Nasal cavity, filled with matrix: p. 530.

Fig. 11. Anterior frontal: p. 530.

The thickness of the anterior and posterior margins are shown in the appended figures.

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Fig. 13. An undetermined bone of *Labyrinthodon*.

Plate XLIV.

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Fig. 2. Inside view of anterior end of the same fossil: p. 526.

a, Anterior and external suture between the angular and dentary pieces.

b, Canal of the angular piece, supporting the dentary: p. 526.

c, *c*, Dentary piece.

d, Anterior prolongation of the angular piece.

Fig. 3. Upper view of ditto: p. 526.

Figs. 4, 5 and 6. Fragments of jaw with teeth of the *Labyrinthodon Jægeri*, from the Warwick sandstone.

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* Two teeth of the same jaw, magnified.

Fig. 8. Portion of left ramus of lower jaw of *Labyrinthodon leptognathus*: p. 521–523.

* Two teeth of the same, magnified.

Fig. 9. Upper view of the same bone.

Plate XLV.

Figs. 1—4. Different views of a portion of a vertebra of *Labyrinthodon pachygnathus*: p. 532.

Figs. 5—8. Different views of a fractured vertebra of *Labyrinthodon leptognathus*: p. 523–524.

Figs. 9 and 10. Two views of the episternal bone of a *Labyrinthodon*: p. 524.

Figs. 11—13. Three views of the proximal half of the humerus of *Labyrinthodon pachygnathus*: p. 533.

Fig. 14. Proximal articulation of the same fossil: p. 533.

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Fig. 16. External view of the right iliac bone of the *Labyrinthodon pachygnathus*: p. 533.

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Fig. 18. Head of the femur of the same species of *Labyrinthodon*: p. 535.

Fig. 19. Coprolite from the same quarry.

Plate XLVI.

Fig. 1. Group of bones of the *Labyrinthodon* (*Anisopus*) *scutulatus*: p. 538.

h, Humerus: p. 539.

ff, Femora: p. 539.

t t, Tibiæ: p. 539.

The fractured ends of the tibia and of a large (jaw?) bone are given above the group.

Fig. 1′. Shows the opposite surface of the large bone.

Fig. 2. Upper view of a vertebra of the same fossil: p. 539.

Fig. 3. The same vertebra magnified, showing the expanded and sculptured summit of the spinous process.

Fig. 4. Side-view, and two ends of the same vertebra, natural size.

Fig. 5. A dermal scute, four times magnified, of the same fossil: p. 538.

Fig. 6. Group of cranial bones of the *Labyrinthodon pachygnathus*: p. 538.

Fig. 7. Side-view of the principal of the preceding bones.

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Fig. 1*. View of the alveoli of the same fossil: p. 537.

Fig. 2. Outside view of a portion of the left ramus of the lower jaw of the same species, from the same locality: p. 537.

Fig. 3. Inside view of the anterior end of the same fossil, showing the beginning of the groove for the dentary piece: p. 537.

PLATE XLVIII.

Illustrates Mr. Strickland's description of a series of coloured sections of the cuttings on the Birmingham and Gloucester railway: p. 545 *et seq.*

The sections given in this plate exhibit the more important geological phænomena exposed along the line of the railway.

Fig. 1. Exhibits the cuttings from Stoke Prior through the summit-level of the Lickey ridge to Longbridge: p. 547.

Fig. 2. In this section the cutting through the Lickey ridge is given on an uniform scale; and the new red conglomerate is shown to rest unconformably on highly inclined strata of the lower new red sandstone: p. 547.

Figs. 3 and 4. Exhibit cuttings through the junction beds of the lower lias and red marl: p. 550, 551.

Fig. 5. Shows the positions of the marine gravel with flints, and the ancient fluviatile deposits with reference to the configuration of the country: p. 554.

WOODCUTS

Explanatory of Mr. Maclauchlan's Notes on Pembrokeshire: pp. 557—560.

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Fig. 2. Section from Llawhaden, near Canaston, to Dinas Head: p. 557—559.

WOODCUT

Exhibiting the phænomena exposed in the cutting at Bleadon Hill on the line of the Bristol and Exeter railway, and described in the communication of the Rev. David Williams: p. 561, 562.

THREE DIAGRAMS

Exhibiting the natural cleavage of quartz-rock (fig. 1.) and slate (figs. 2, 3.), noticed in the extract from the Rev. W. B. Clarke's paper on the Cotentin: p. 565, 566.

TWO WOODCUTS,

Of veins of gravel in granite exposed on the north-west coast of Guernsey. The circumstances connected with these veins are described in the extract from a letter by W. C. Trevelyan, Esq.: p. 567.

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32
34
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36
34
BLACK SEA
EUROPE
Burgas
Midiah
Bosphorus
CONSTANTINOPLE
Erekli
Marri
Enos
Ganos
SEA OF MARMORA
Izmid
Samothraki
G. of Xeros
Hellespont
Imbros
Dardanelles
Lemnos
Tenedos
M. Ida
Adramytti
G. of Adramytti
Mytilene
Port Kalona
Scio
Samos
Nikaria
Patmos
Leros
Levita
Kos
G. of Kos
Amorgo
Stampalia
Piscopia
Anaphi
Rhodes
G. of Makry
Makry
Scarpanto
Caso
Spina longa
Cyprus
Nicosia
C. Salizano
Baffa
Famagosta
Karpasia
Limassol
C. Andreas
Cerinos
Mezetlu
Missiaoul Kalipeh
C. Gavalivri
C. Anamur
Kandivar
Silifke
Alaya
Esky Adalia
Adalia
C. Avova
Adratchan B.
Finicha Bay
Port Fathy
Makry
Karagia-aghatch B.
Boodroom (anc. Halicarnassus)
Deenair
Hierapolis
Tralles
Meander R.
Caystr R.
Sighajik
Smyrna
Nimphi
M. Tmolus
Sardis
Gegean L.
Adalia
Lydia
Thyatira
Sattle Ks.
Kaiaccau
Sorkonum
Ushak
Kalidikese
Tuksnak
Aktash
Karadja
Bonarja Dagh
Morad Dagh
Sultan Dagh
Ak shehr L.
Tuzlhieul
M. Argæus
Hassan Dagh
Koniych
L. Beg shehr
Kara Dagh
L. Seidi shehr
Taurus Range
M. Cadmus
M. Latmus
Latmic L.
Myonnesus
Priene
Miletus
Myonte
Erythræ
Ephesus
M. Mesogis
Sinaud
Ak Dagh
Chiediz
Azani
Gozuljah
Taushanli
Eshiri
Harmanjik
Haidar
Eski Shehr
Kutaya or Kutahiyah
Angora
Kalehjik
Osmanjik
Chorum
R. Halys
R. Sangarius
Bartan
Bartan R.
Kastamuni
Bai-abad
Gok Irmak
Zafran Boli
Inebali
Sinope
C. Boztepeh
C. Indjeh
Bosphorus Prom.
G. of Moudania
Brusa
Moudania
Apollonia
Bullionte
L. Maniyas
M. Olympus
Kirmasli
Susughirli
Tash Kopu
Ildiz
Kebzat
Kalhourja
Boghaditza
Sinjerli
Bigeotus
Bijah
Munjik
Demirji M.
Caicus R.
Karabornou
Pergamus
G. of Smyrna
Val. Lydiæ
Hermus R.
Gegean L.
Adalia
Thyatira
Sattle Ks.
Kaiaccau
Sorkonum
Ushak
Kalidikese
Tuksnak
Aktash
Karadja
Bonarja Dagh
Morad Dagh
Sultan Dagh
Ak shehr L.
Tuzlhieul
M. Argæus
Hassan Dagh
Koniych
L. Beg shehr
Kara Dagh
L. Seidi shehr
Taurus Range
M. Cadmus
Deenair
Hierapolis
Tralles
Meander R.
Caystr R.
Sighajik
Smyrna
Nimphi
M. Tmolus
Sardis
Gegean L.
Adalia
Lyd

GEOLOGICAL MAP
of the
CATACECAUMENE,
to Illustrate a Memoir
on Part of
ASIA MINOR,
by
W. J. Hamilton Esq.r Sec. G.S.
and
Hugh Edwin Strickland Esq.r F.G.S.
Schistose and Metamorphic Rocks
Micaceous Sandstone
Lacustrine Limestone
Alluvial
Basalt of First Second Period
Most recent Lava Basalt of 3rd Period
Craters of 3rd Period
Hermus fl.
Tetrakum
Koola
Sandal
Ghiaurdi
Trachete
Gemmus fl.
Adalia
Rhinus of Scutter
Old Cone

SECTIONS IN ASIA MINOR AND SECTIONS AND VIEWS IN THE CATACECAUMENE.

to illustrate the Memoir of Mr. Allen and Mr. Strickland.

U M E N E

o H U S H

M E N E.

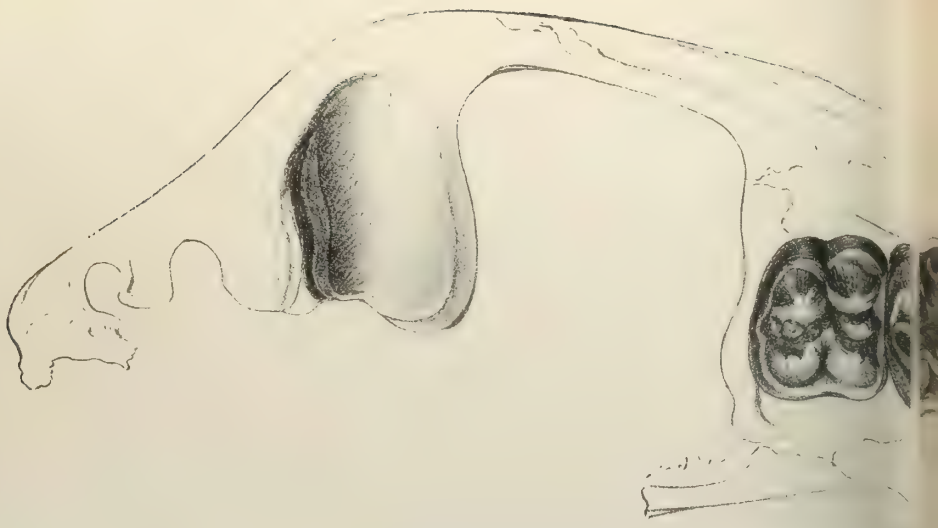
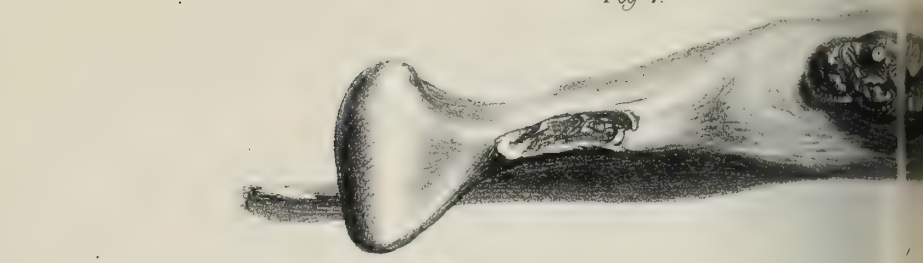


Fig 1.



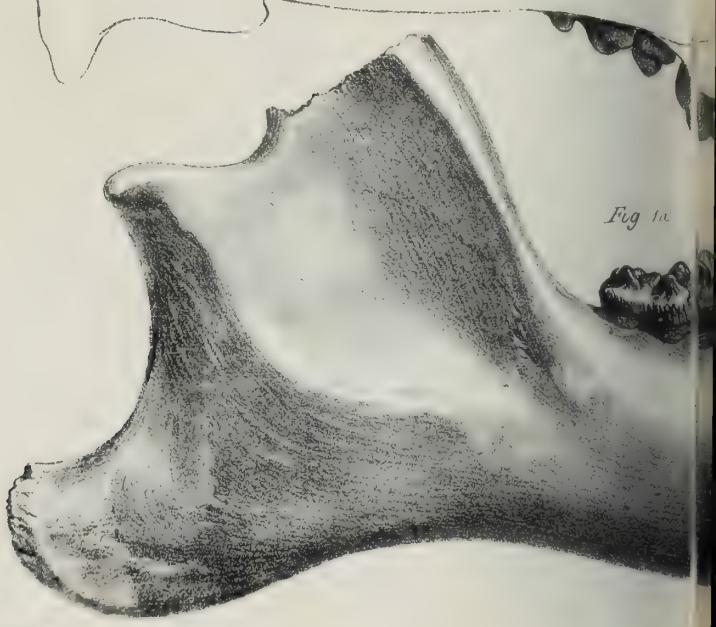


Fig 1a

Lithog. from Nat. by G. Scharf

Fig 2

Fig. 4

Fig. 3

Fig. 5

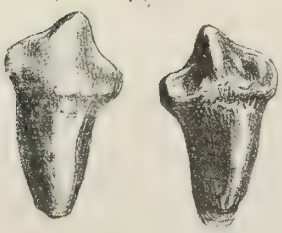
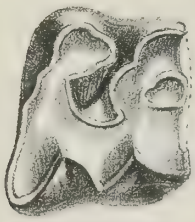


Fig. 6.



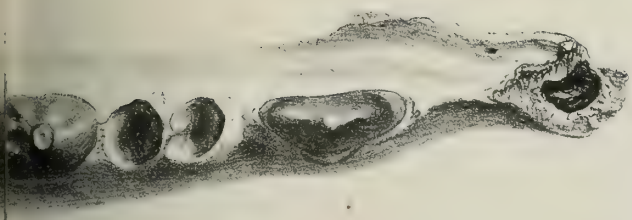


Fig. 7

Fig. 3a

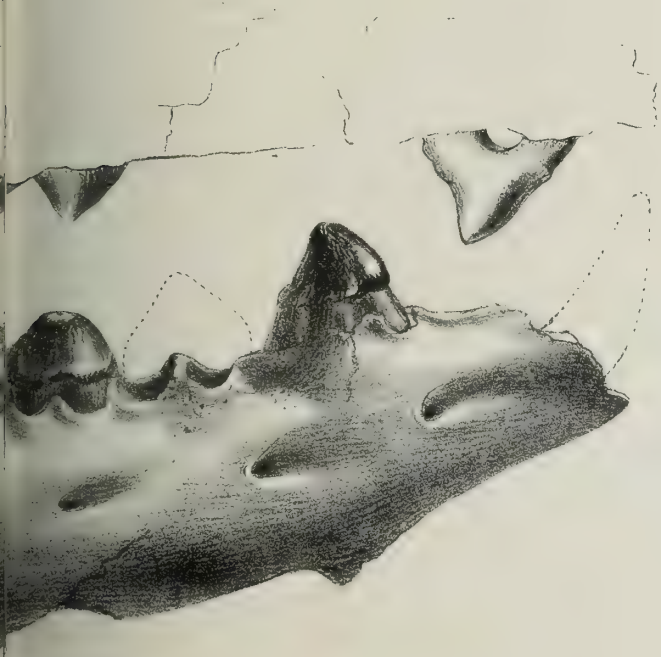
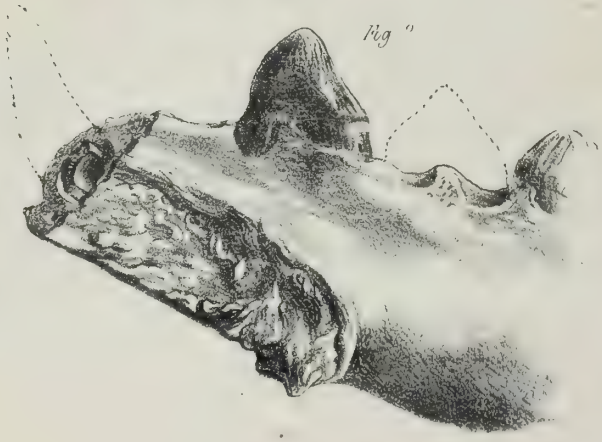


Fig. 8



f Wight p. 41. et seq.

Anoplotherium Fig. 6. 7 Palæotherium

i Size

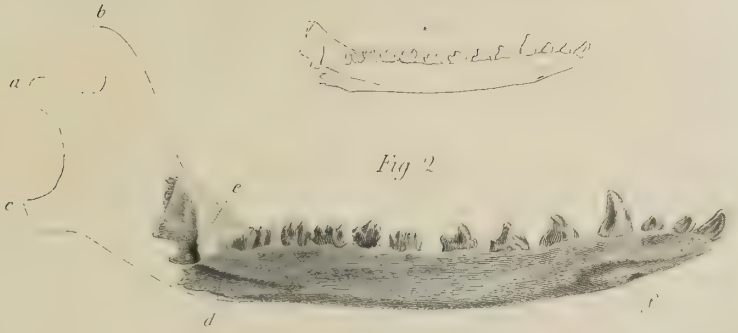


Fig. 1 & 3 Thylacotherium Prevostii Fig. 2 Myrmecobius

The outline figures are of the natural size

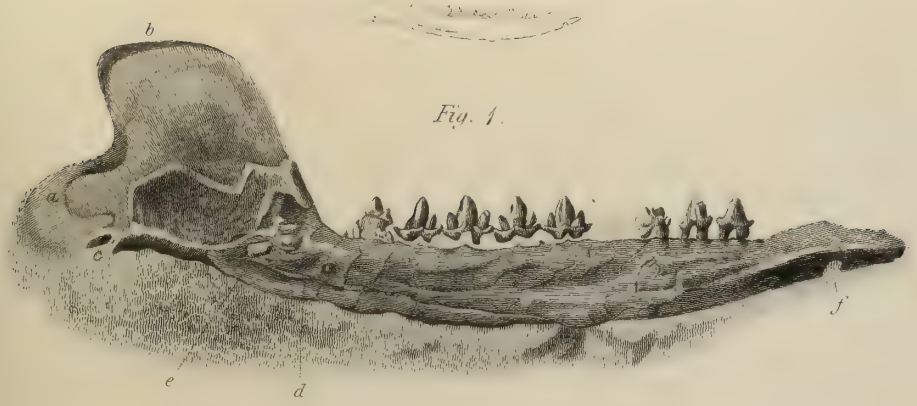


Fig. 1.

Fig. 2

Fig. 1 Thylacotherium Broderipii Fig. 2 Phascolotherium Bucklandi.

The outline figures are of the natural size

a

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les (Owen)

l Size) p 69 et seq

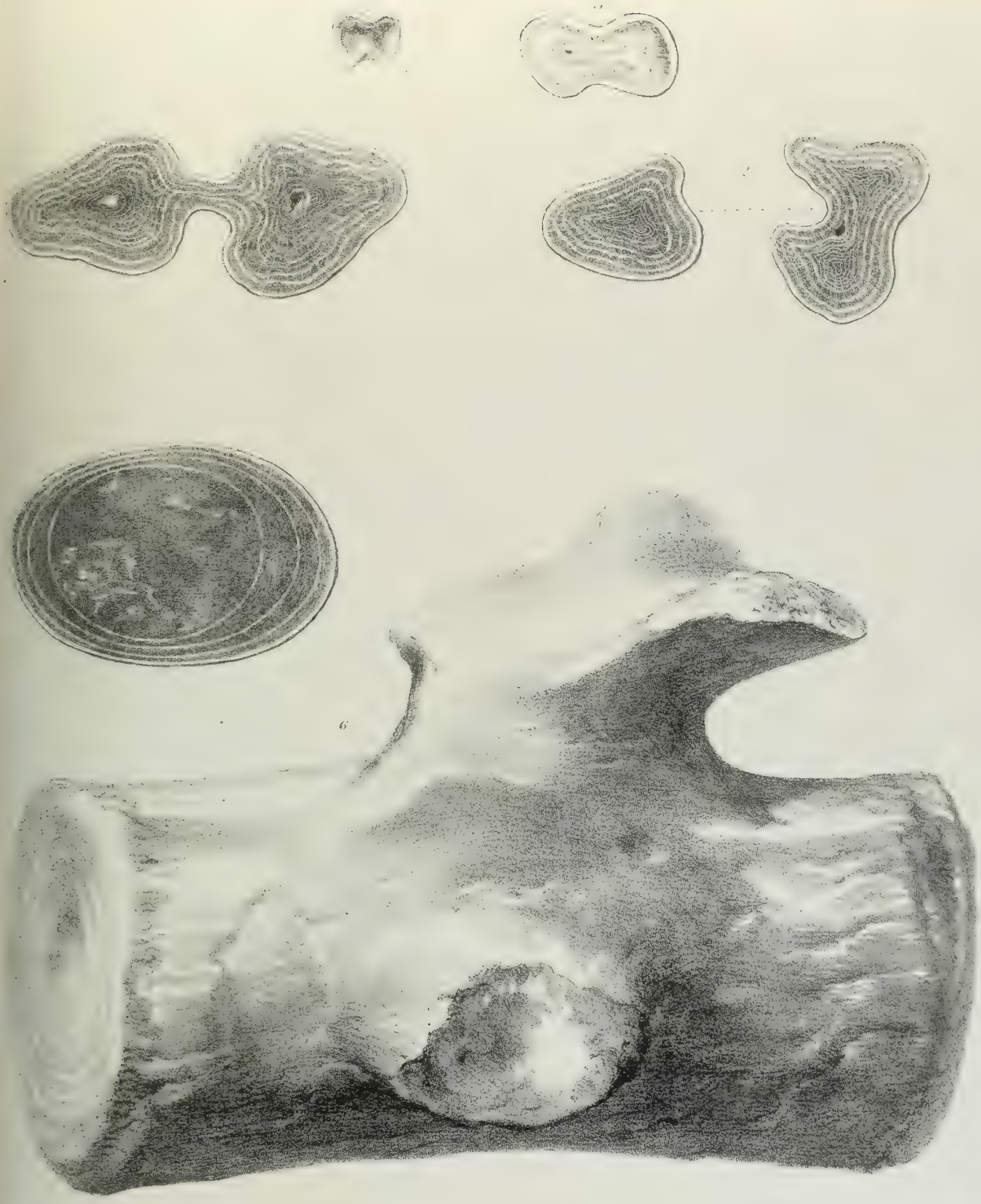

Fig. 1, 2, 5 & 6 Zeuglodon Cetoides Owen

Fig. 1 & 2 Sections of Teeth p. 70 Fig. 5 Section of a Rib p. 77
Fig. 6 Caudal Vertebra p. 76
Fig. 3 Transverse Section posterior molar Dugong p. 72
Fig. 4 Crown of a worn molar of the Manatee p. 72

Lithog. from Nature by G Scharf

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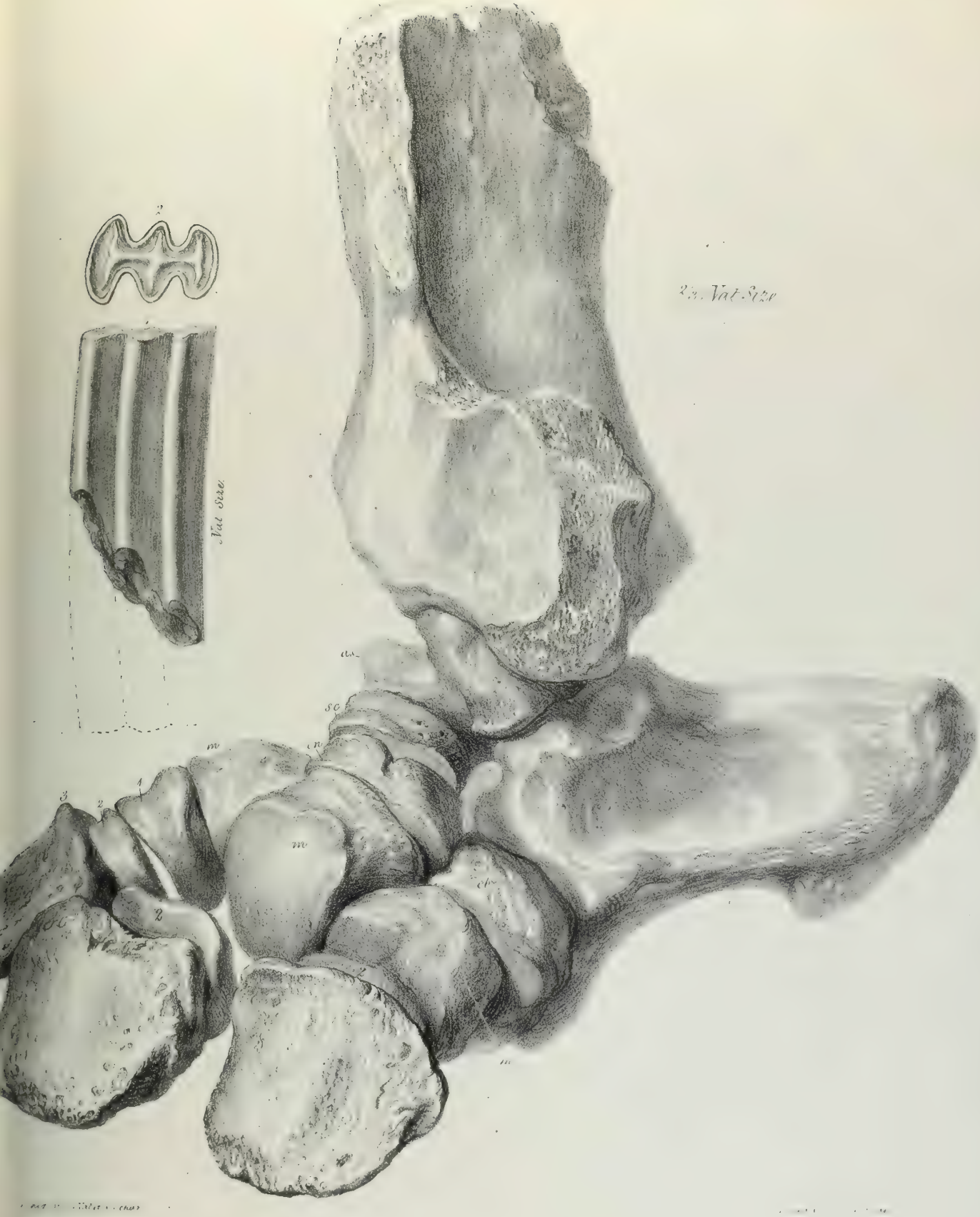
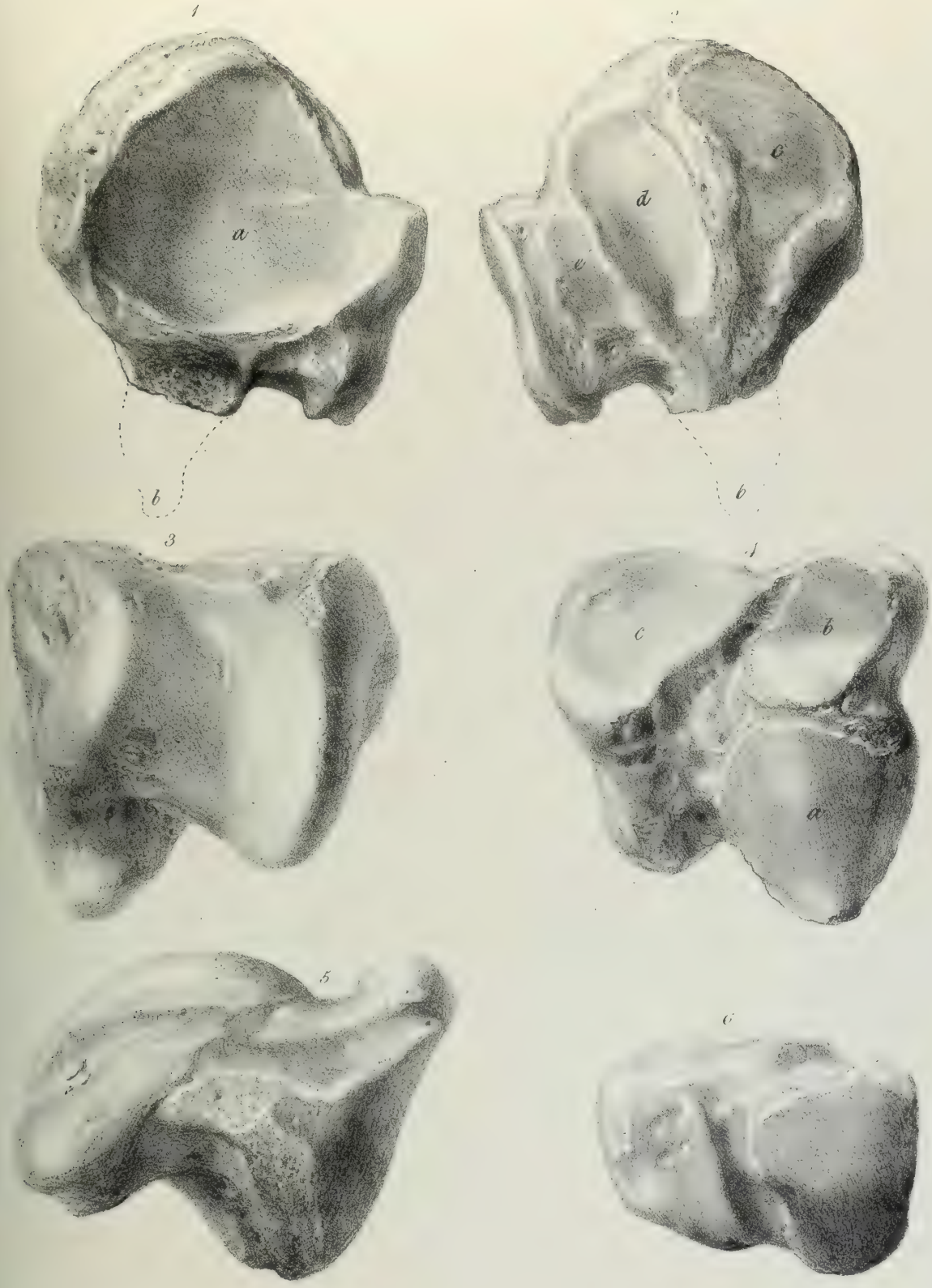
Humerus of the Zeuglodon Cetoides (Owen.)

Half the Nat Size p 78.



Glyptodon clavipes

Fig 1 & 2 Side View and grinding surface of Molar p 86
Fig 3 Outside View of left hind foot p 90 et seq



Lithog from Nat by G Scharf

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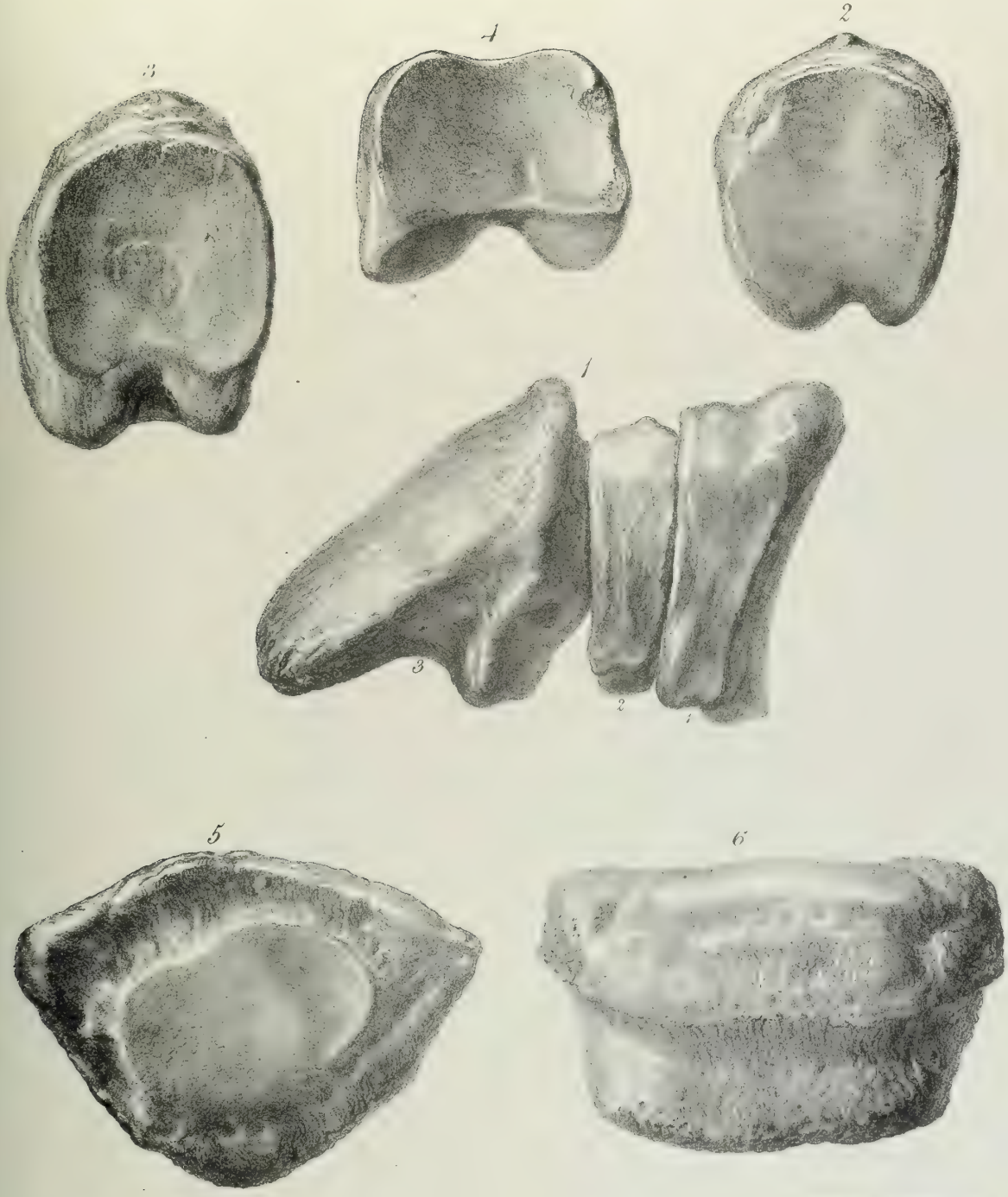
Glyptodon clavipes

Fig 1 & 2 Os scapoides p. 92 Fig 3_5 Astragalus p 90 Fig 6 Os cuboides p 93.

2/3 Nat Size



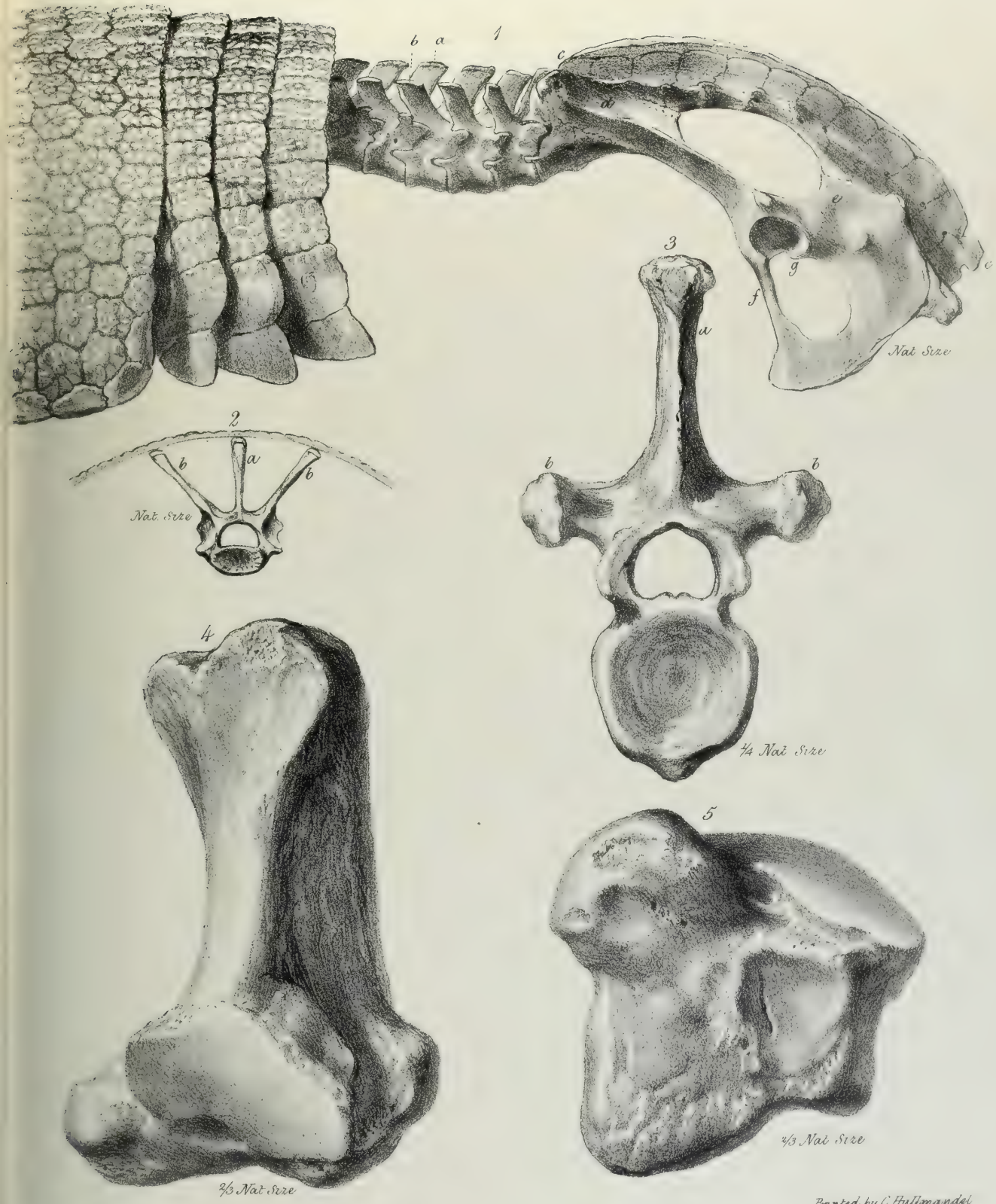
Lithog from Nat by G Scharf

Printed by J Hullmandel

Glyptodon clavipes

Fig 1 2 3 & 5 The three phalangeal Bones of the second Toe p 94 Figs 1 & 6 Nat Size

Fig 4 Middle Phalanx of the third Toe p 95 Fig 6 Ungual Phalanx of the third Toe p 95



Lithog from Nat by G Scharf.

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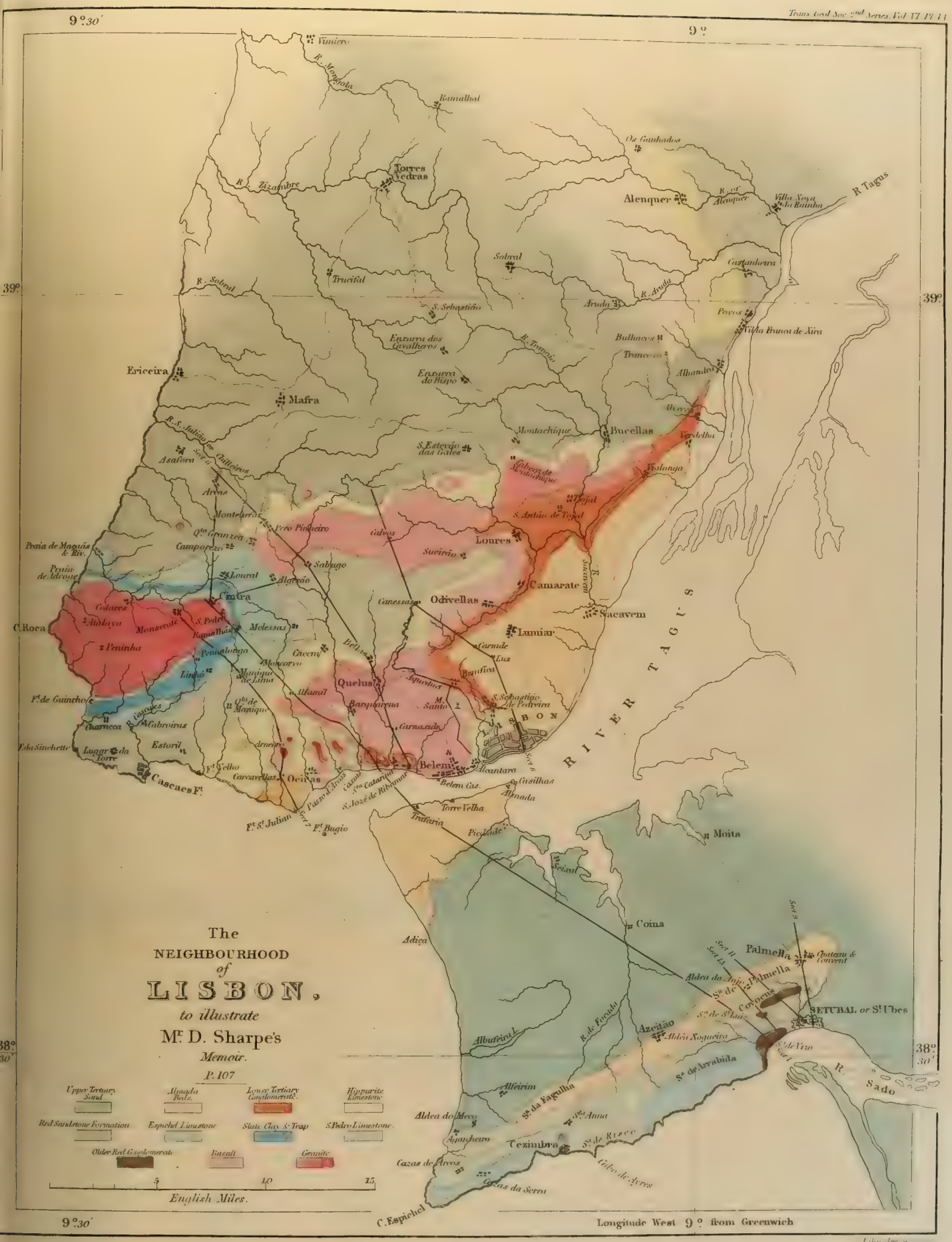
Dasypus p. 98. Fig 3. Lumbar Vertebra, Megatherium p 101. Fig 4 & 5 Calcaneum, Glyptodon clavipes p. 91

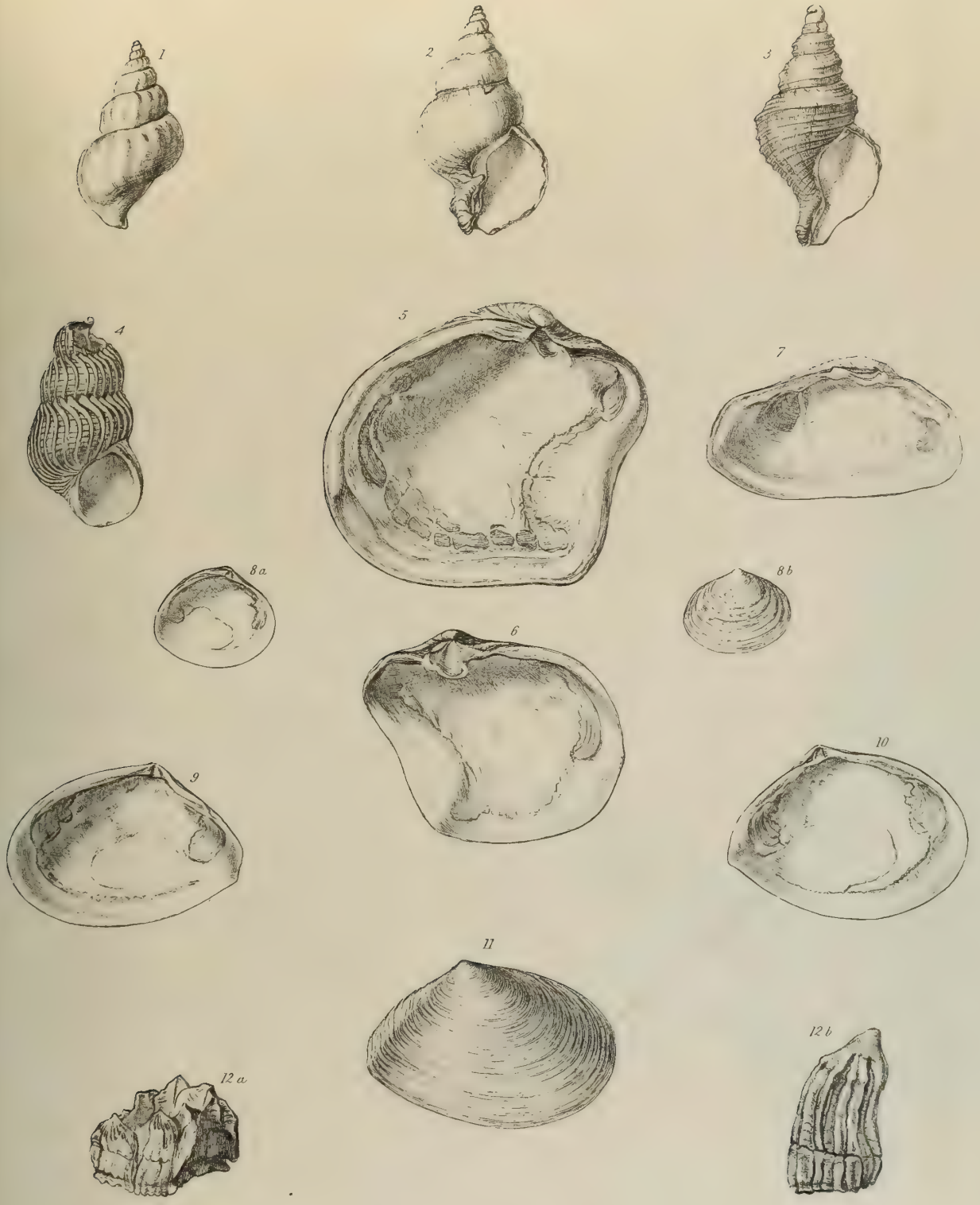

The
NEIGHBOURHOOD
of
LISBON,
to illustrate
Mr. D. Sharpe's
Memoir.
P. 107
Upper Tertiary Sand
Almada Beds.
Lower Tertiary Conglomerate.
Hippurite Limestone
Red Sandstone Formation
Espichel Limestone
Slate Clay & Trap
S. Pedro Limestone.
Older Red Conglomerate
Basalt
Granite
5
10
15
English Miles.
9°30′
9°
39°
38° 30′
Longitude West 9° from Greenwich
Vimiero
R. Mongola
Ramalhal
Os Ganhados
Torres Vedras
R. Zizambre
Alenquer
R. or Alenquer
Villa Nova da Rainha
R. Tagus
Sobral
Castanheira
Trucifal
R. Sobral
R. Aruda
Aruda
S. Sebastião
Povos
Villa Franca de Xira
Enxarra dos Cavalheiros
R. Tranoio
Bulhacos
Trancozo
Ericeira
Enxarra do Bispo
Alhandra
Mafra
Alverca
Montachique
Bucellas
Verdelha
R. S. Julião or Chilleiros
S. Estevão das Gales
Asafora
Cabeça de Montachique
Vialonga
Areas
Tojal
Montelavar
S. Antão de Tojal
Pero Pinheiro
Qta. Granzea
Calvos
Loures
Praia de Maçaãs & Riv.
Camporezo
Sucirão
Sabugo
Praia de Adrage
Loural
Algerão
Camarate
Cintra
Canessas
Odivellas
Colares
Sacavem
C. Roca
Atalaya
Monserate
S. Pedro
Ramalhão
Melessas
Lumiar
Peninha
Pennalonga
Cacem
Bellas
Carnide
Luz
Monçorvo
Benfica
Linhó
Manique de Lima
Quelus
Aqueduct
Alfamil
Barquarena
M. Santo
S. Sebastião de Pedreira
Ft. de Guincho
Qta. de Manique
LISBON
Charneca
Cabroiras
Carnaxide
Estoril
Lugar da Torre
Belem
Alcantara
Ft. Velho
Carcavellas
Oeiras
Cascaes Ft.
Belem Cas.
Casilhas
Almada
Torre Velha
Ft. St. Julian
Ft. Bugio
Trafaria
Piedade
Moita
Seixal
Coina
Adiça
Palmella
Chateau & Convent
Aldea do Anjo
Sa. de Palmella
Covoens
SETUBAL or St. Ubes
Sa. de St. Luiz
Azeitão
Aldea Nogueira
Albufeira L.
R. de Focada
Sa. de Arrabida
R. Sado
Alfeirim
Sa. da Fagulha
Sta. Anna
Aldea do Meco
Agancheiro
Cezimbra
Sa. de Risco
Cazas de Arcos
Cabo de Ayres
Cazas da Serra
C. Espichel
RIVER TAGUS

Trans. Geol. Soc. 2nd Series Vol. VI. Pl. 15.

SECTIONS TO ILLUSTRATE Mr. D. SHARPE'S PAPER ON THE NEIGHBOURHOOD OF LISBON.

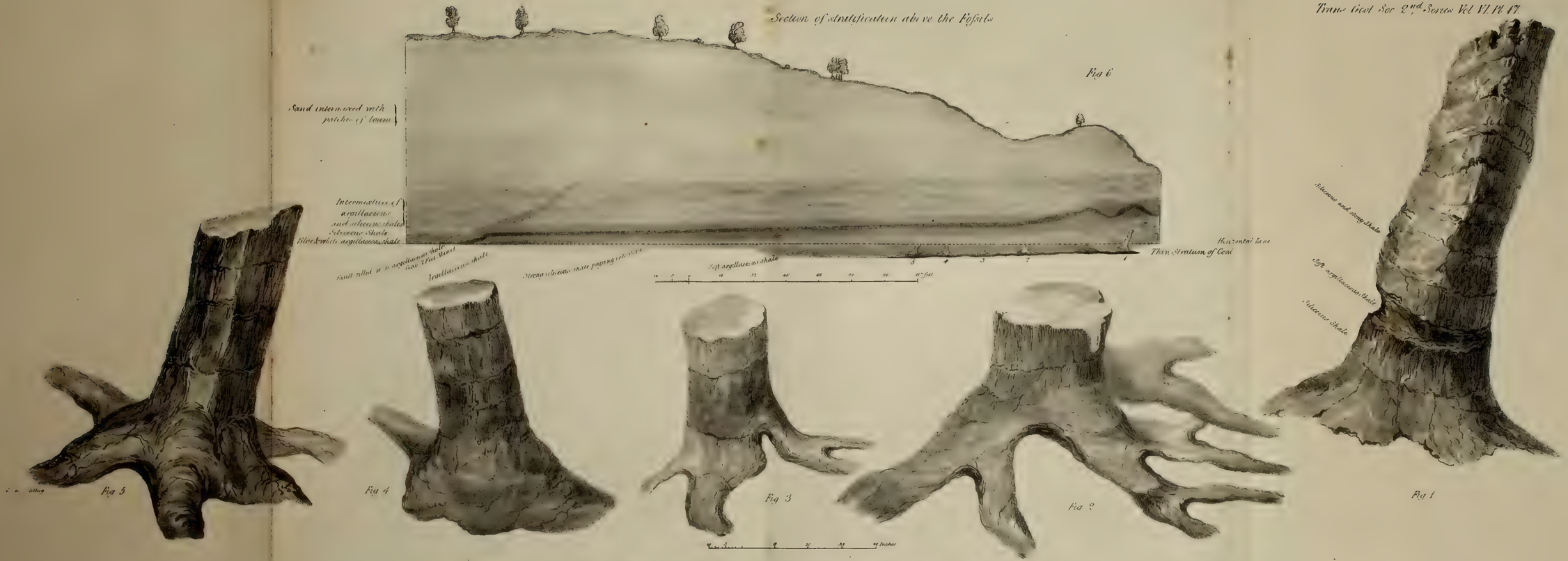
P. 107

The Figures under the lines of Section denote the Angle of the dip of the Strata



Fossils from the modern deposits near Quebec, Canada

E. B. Sowerby



Fossil Trees discovered at Dixon Fold on the line of the Manchester and Bolton Railway p 173.

Siliceous and stony Shale
Soft argillaceous Shale
Siliceous Shale

Fig 1.

Fig. 1.

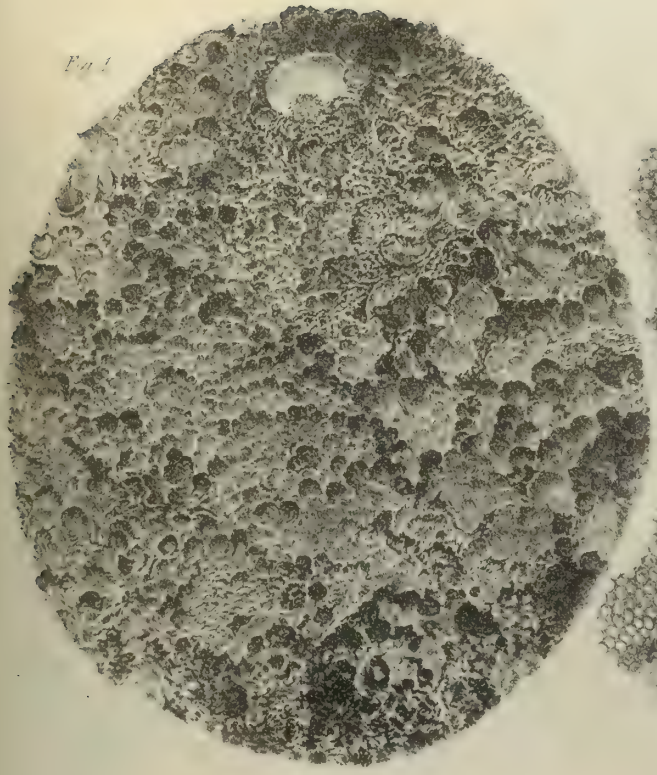


Fig. 2.

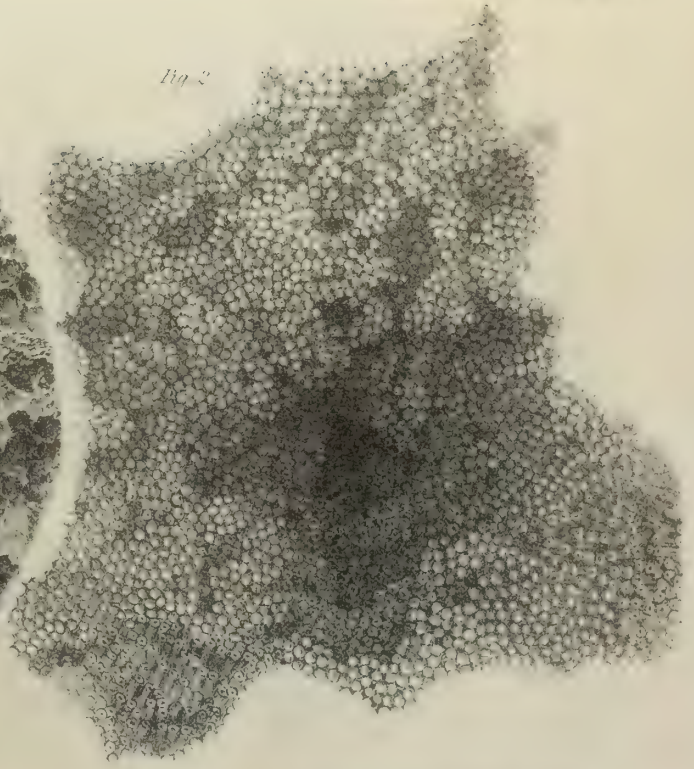
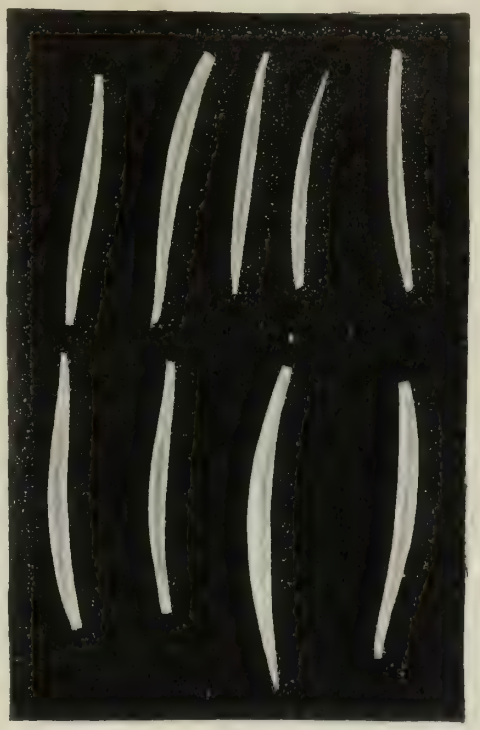


Fig. 3.

Fig. 4.



S. Sidnus Del. et Lith.

Day & Haghe Lith. to the Queen.

Fig. 1 & 2. Portions of the Chalk Flint Sponge mag. 120 times.

Fig. 3 & 4. Spicula of the Chalk Flint Sponge mag. 35 times.

Fig 1

Fig 3.

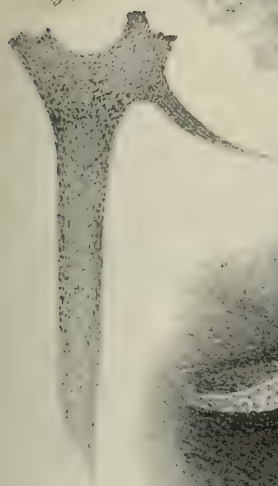
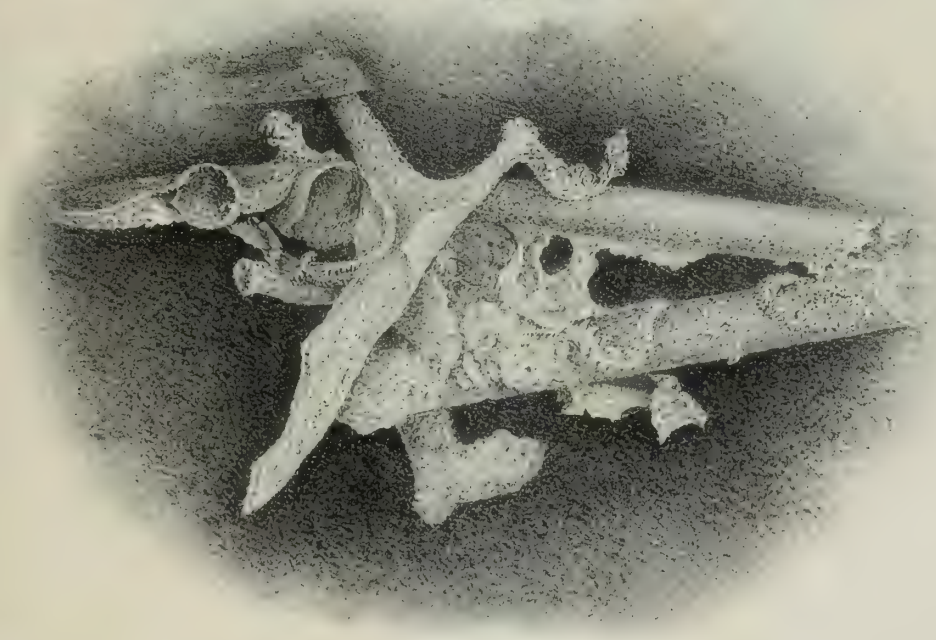


Fig. 2



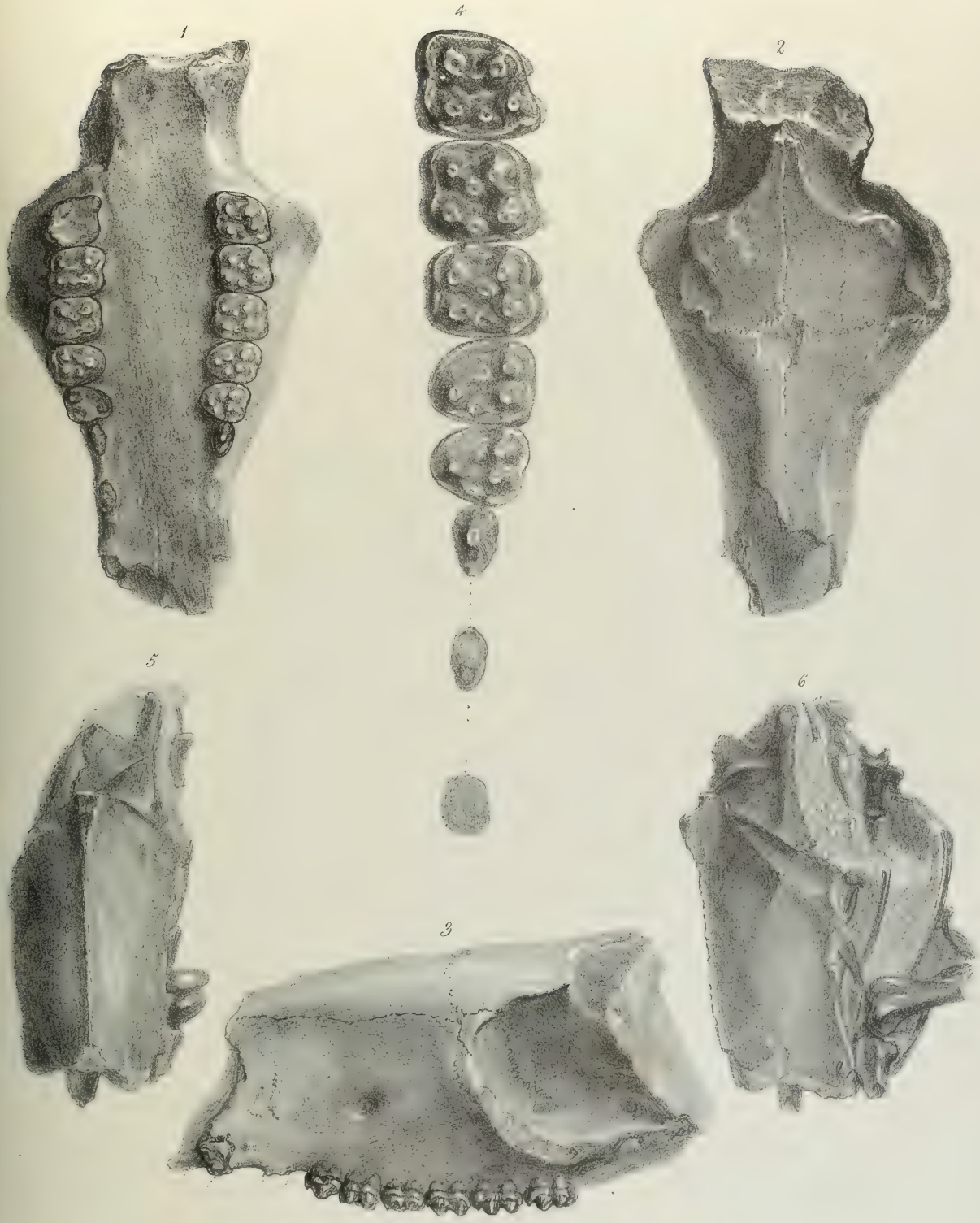
Lens Aldous del et Lith.

Day & Hagh Lith to the Queen

Mag. 50 times

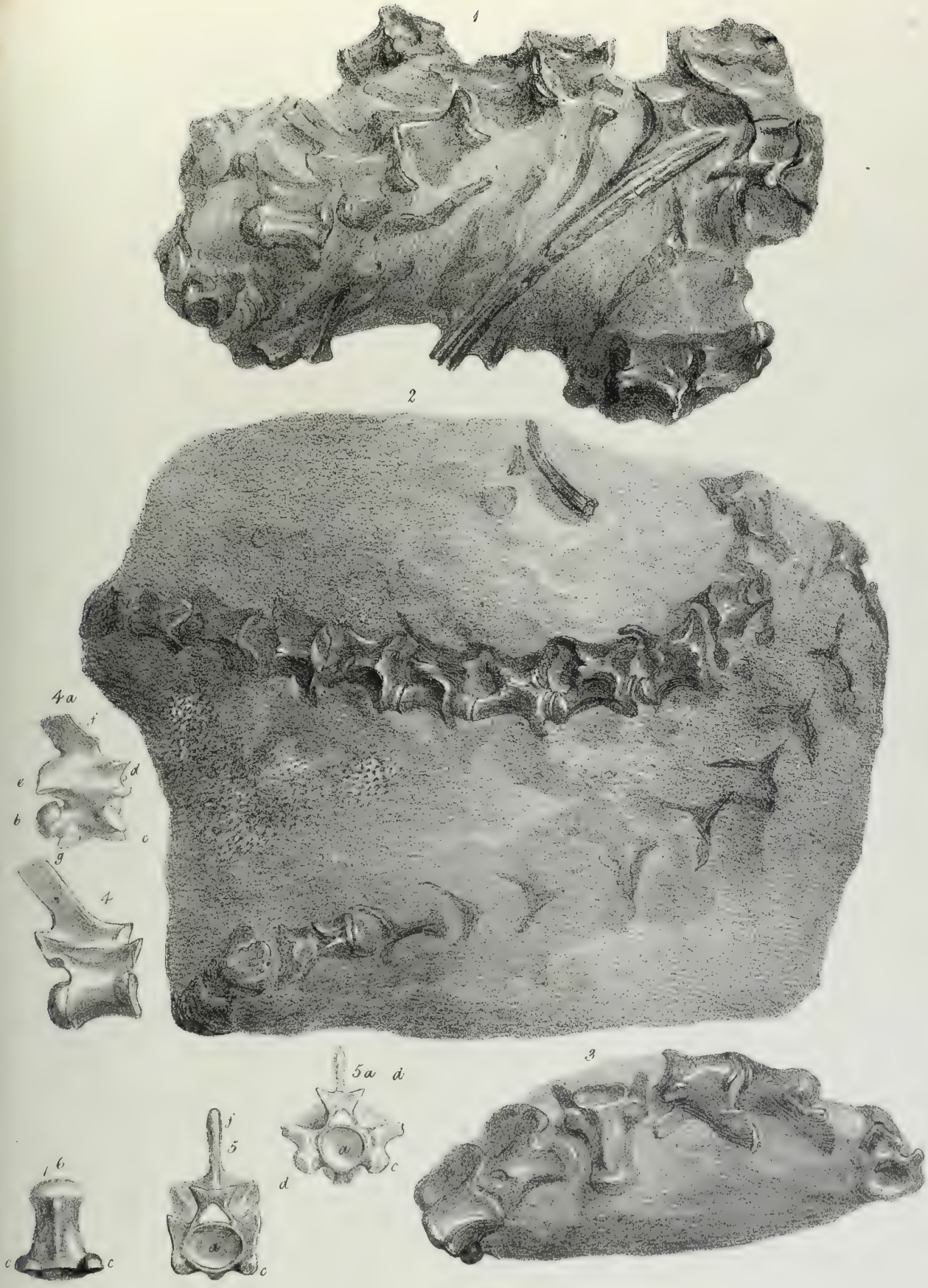
Fig 1 Sponge Fibres and Spicula in Upper Green Sand Chert
Fig 2 & 3 Sponge Fibres in Green Sand Chert, Lyme Regis

Ichthyosaurus.



g from Nature by G. Scharf

1_4 Hyracotherium p 203 to 206 5 6 Lithornis p 206 to 208
Nat Size



Lithog. from Nature by G. Scharf

Palæophis toliapicus

Fig. 1.

General Succession of the older Stratified Rocks in GERMANY AND BELGIUM

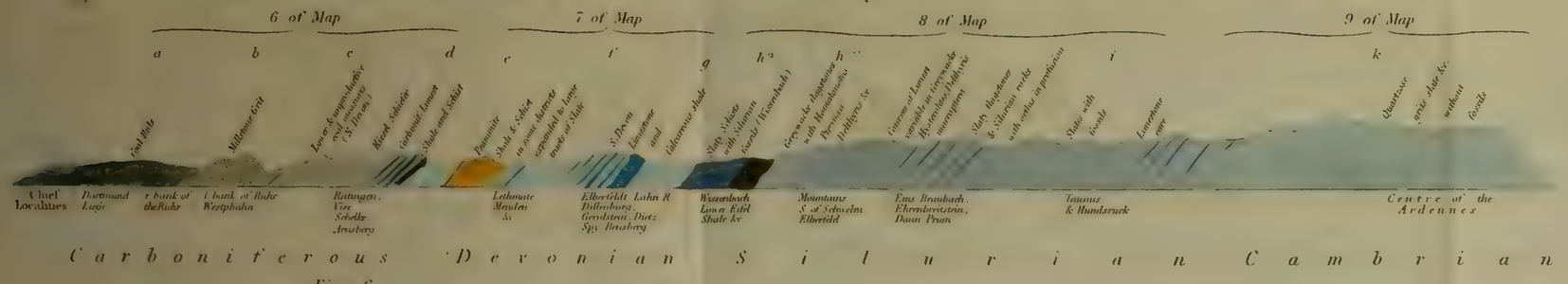


Fig. 2.
p. 228.

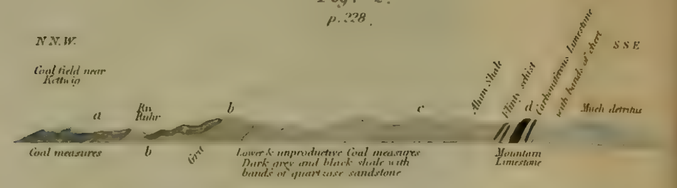


Fig. 6.

General Succession of the Strata near DILLENBURG (trap omitted)
p 244.253.256

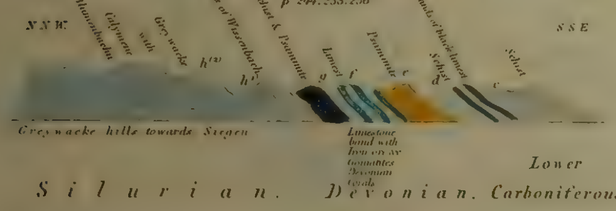


Fig. 7.
p. 241, 253, 256

Natural transverse Section to the East of DILLENBURG
(Horizontal Scale extended)

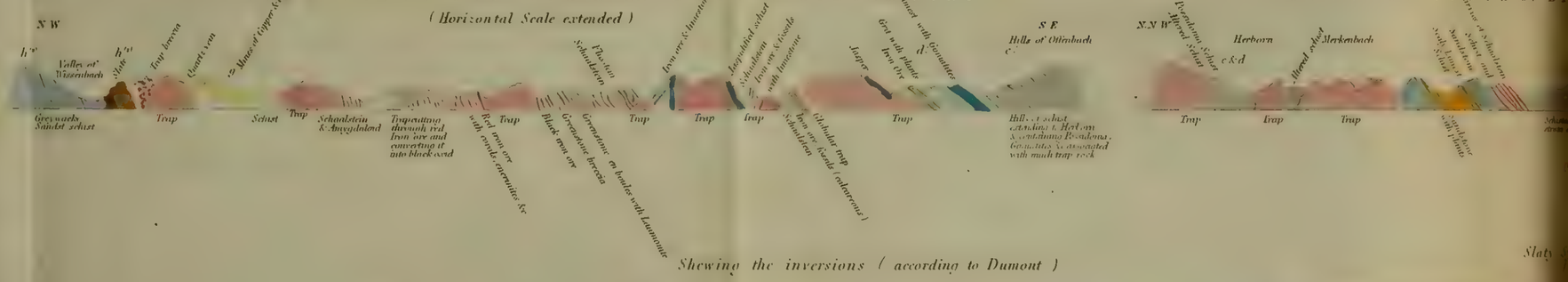


Fig. II.
p. 244

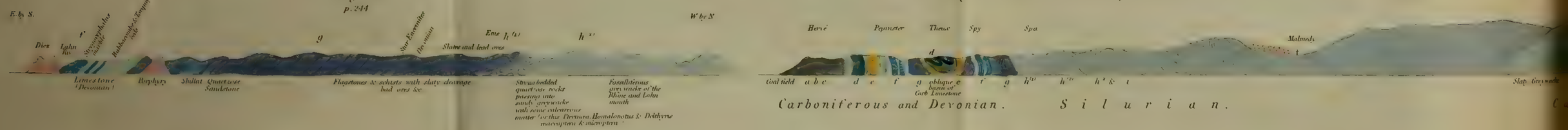


Fig. 14.
p 267
The Eifel

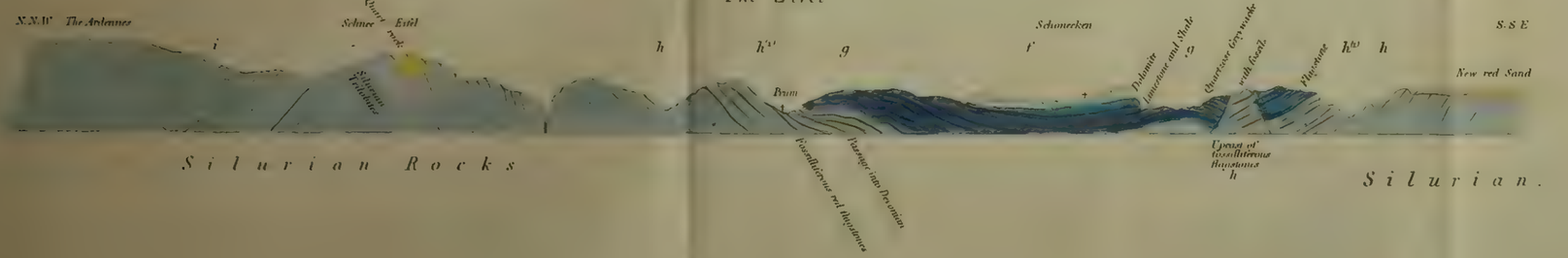
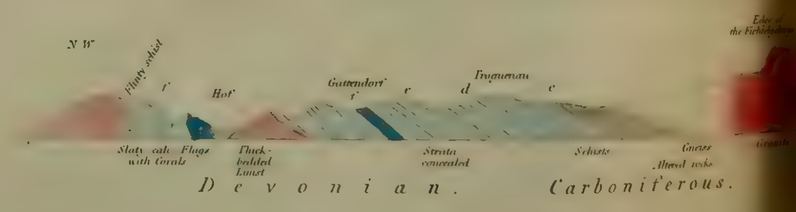
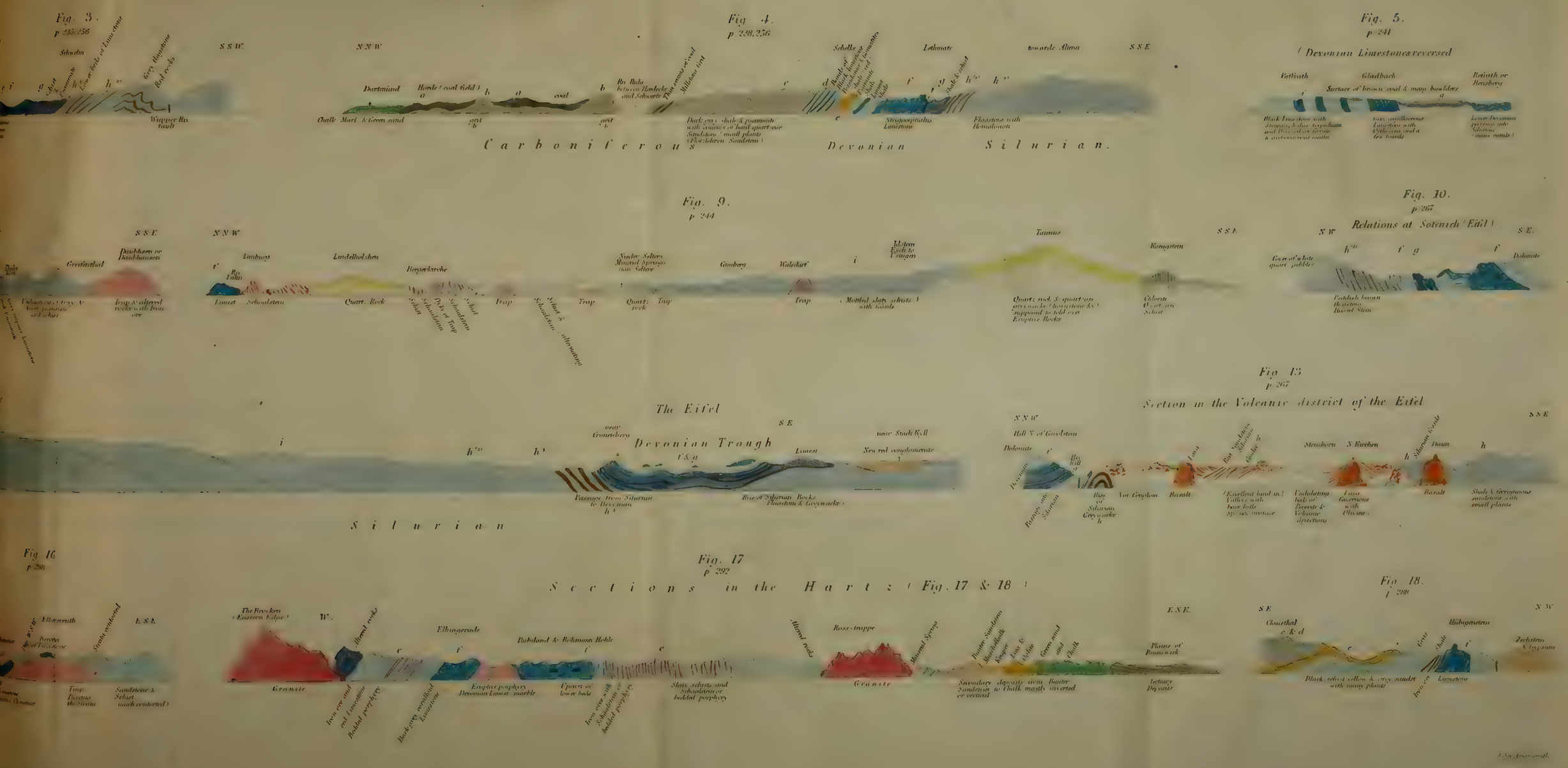


Fig. 15.
p 298
Sections in Ober Frankewald (Fichtelgebirge



ND Mr MURCHISON, ON THE RHENISH PROVINCES &c. P. 221 et seq.



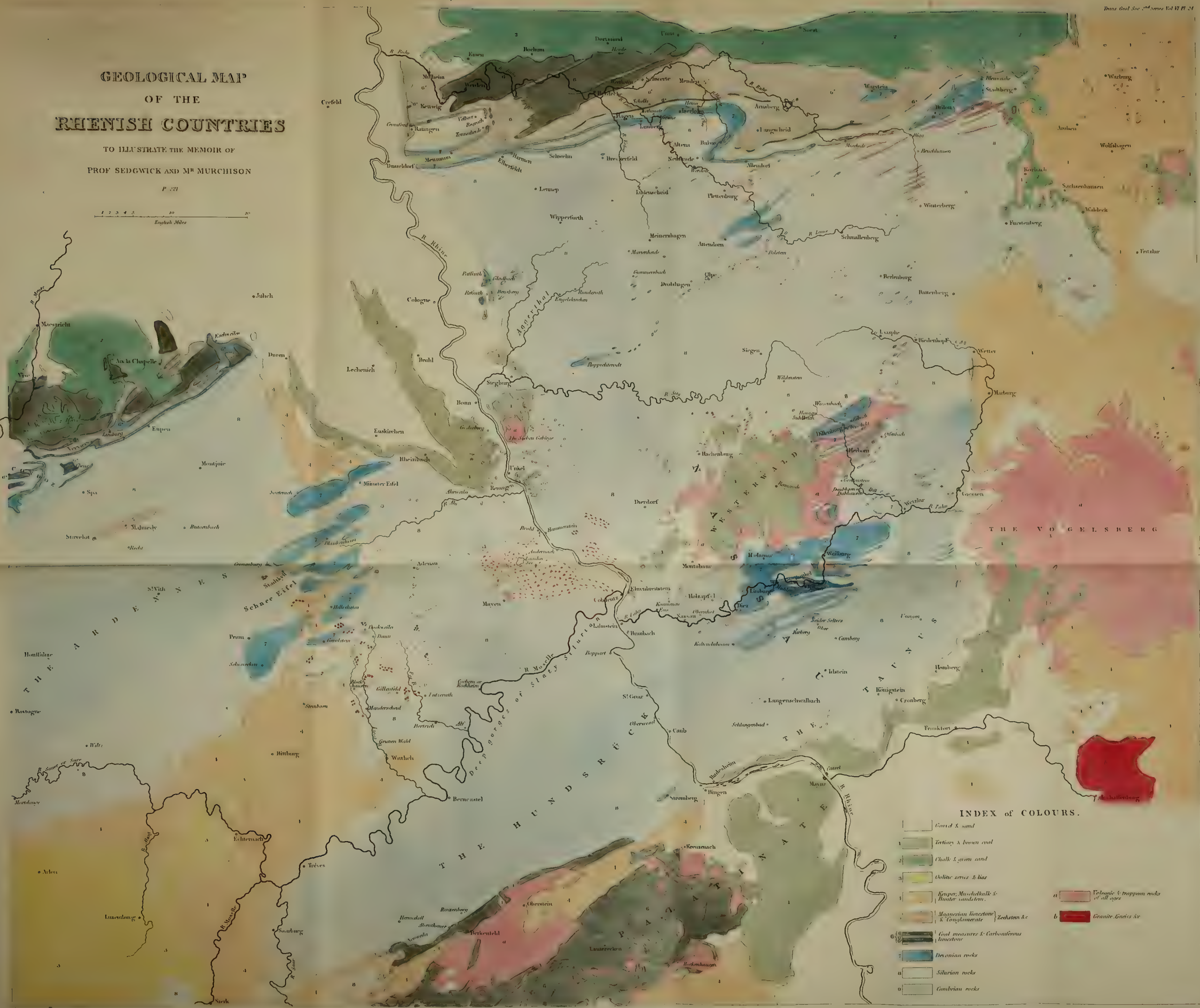
GEOLOGICAL MAP OF THE RHENISH COUNTRIES

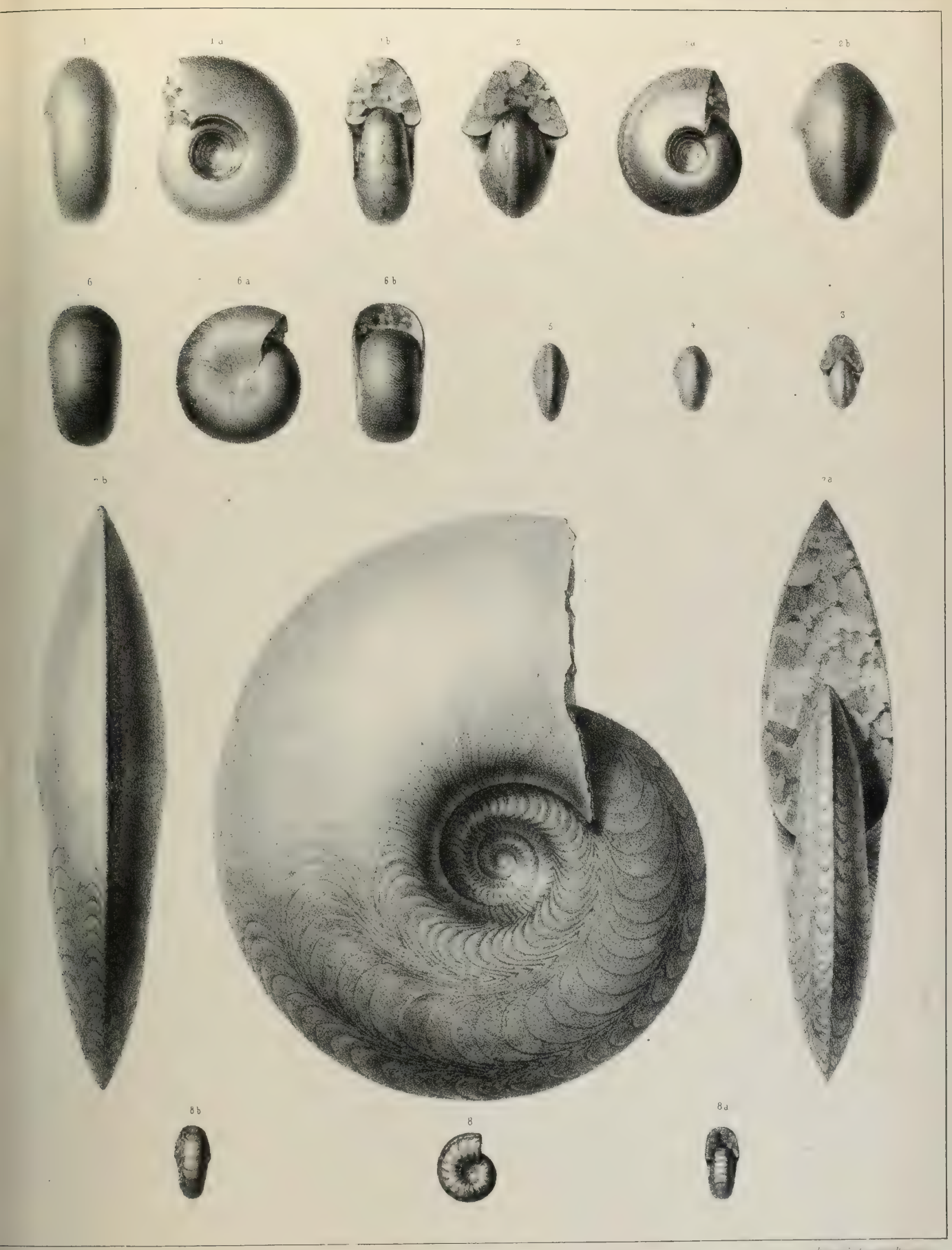
TO ILLUSTRATE THE MEMOIR OF

PROF. SEDGWICK AND Mr. MURCHISON

P. 221

1 2 3 4 5 10 20
English Miles


Crefeld
Düsseldorf
Elberfeldt
Barmen
Lennep
Wipperfurth
Cologne
Bonn
Siegburg
Euskirchen
Rheinbach
Lechenich
Brühl
Juliers
Aachen
Eupen
Montjoie
Spa
Stavelot
Malmedy
Butgenbach
Maestricht
Duren
Mayen
Andernach
Coblenz
Ehrenbreitstein
Boppart
St. Goar
Caub
Bingen
Stromberg
Kreuznach
Oberstein
Berncastel
Bitburg
Prüm
Saarburg
Trèves
Echternach
Luxemburg
Arlon
Bastogne
Wiltz
Sierck
Saarbrücken
Homburg
Zweibrücken
Landau
Mannheim
Mainz
Cassel
Marburg
Giessen
Wetzlar
Frankfurt
Fritzlar
Arolsen
Wolfhagen
Korbach
Sachsenhausen
Waldeck
Fürstenberg
Winterberg
Schmallenberg
Brilon
Warburg
Stadtberg
Iserlohn
Hagen
Lüdenscheid
Plettenberg
Altena
Meinerzhagen
Attendorn
Olpe
Siegen
Dillenburg
Herborn
Weilburg
Limburg
Diez
Nassau
Braubach
Kaiserslautern
Bingen
Kreuznach
Berncastel
Saarburg
Sierck
Echternach
Trèves
Luxemburg
Arlon
Bastogne
Wiltz
Bitburg
Prüm



Thiolat del

Fig 1 1ª 1ᵇ Goniatites Naggerathii de Buch
2 2ª 2ᵇ " " retrorsus id

Fig 5 Goniatites retrorsus var b
6 6ª 6ᵇ Cancellatus nob

Thiolat del

Printed by Lemercier Benard et C

Fig 1,1a,1b Goniatites Buchii nob
2,2a ..... id var
3,3a,3b ..... costulatus nob

Fig 4,4a,4b Goniatites tuberculoseus nob.
5,5a ..... latestriatus nob
6,6a ..... incertus nob.

Fig 7,7a,7b Goniatites tenuistriatus nob.
8,8a ..... id. junior
9 ... Aptychus vetustus nob

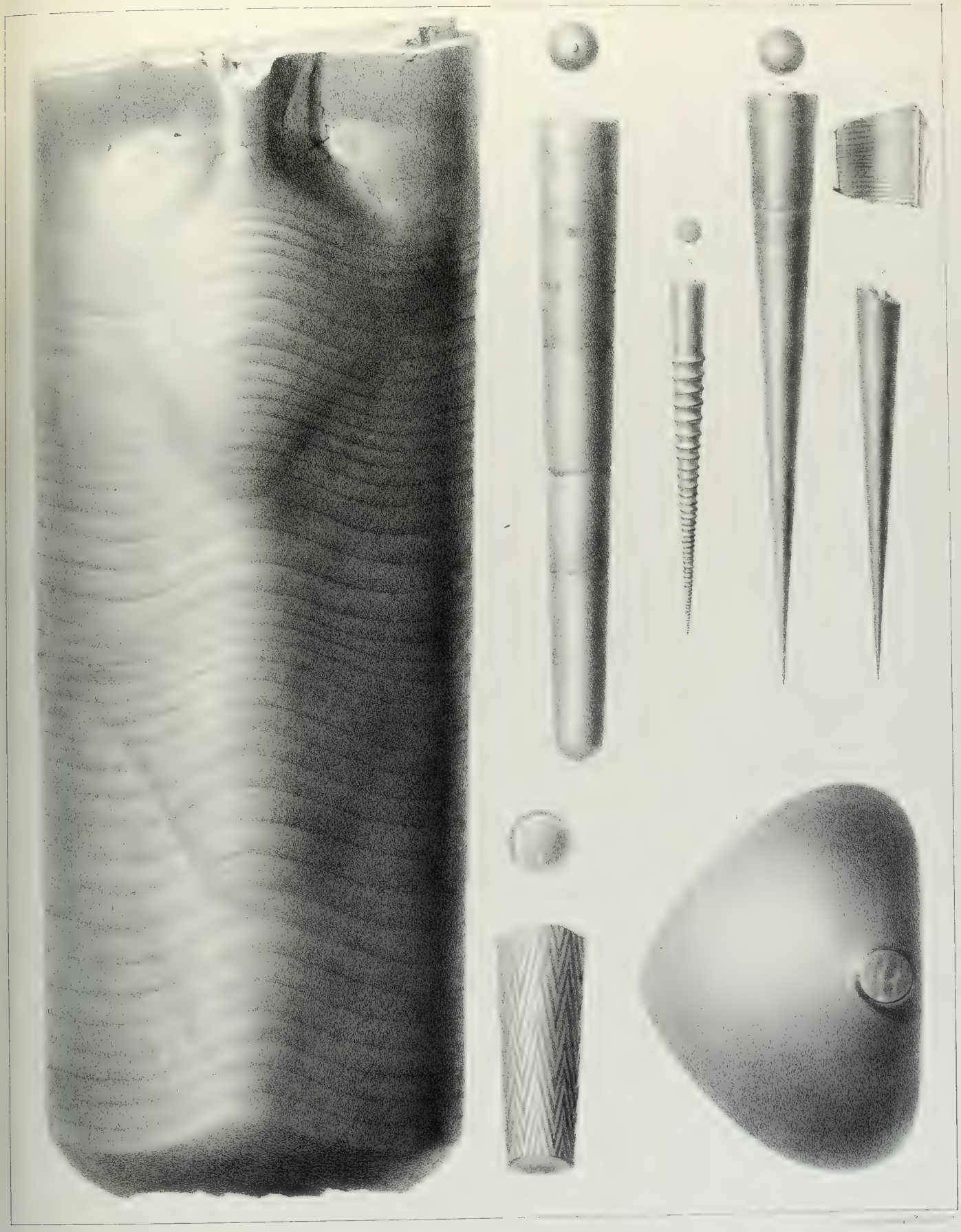


Fig. [illegible] Orthoceratites [illegible] nov.
regularis var. [illegible]
Wissemaeck. [illegible]

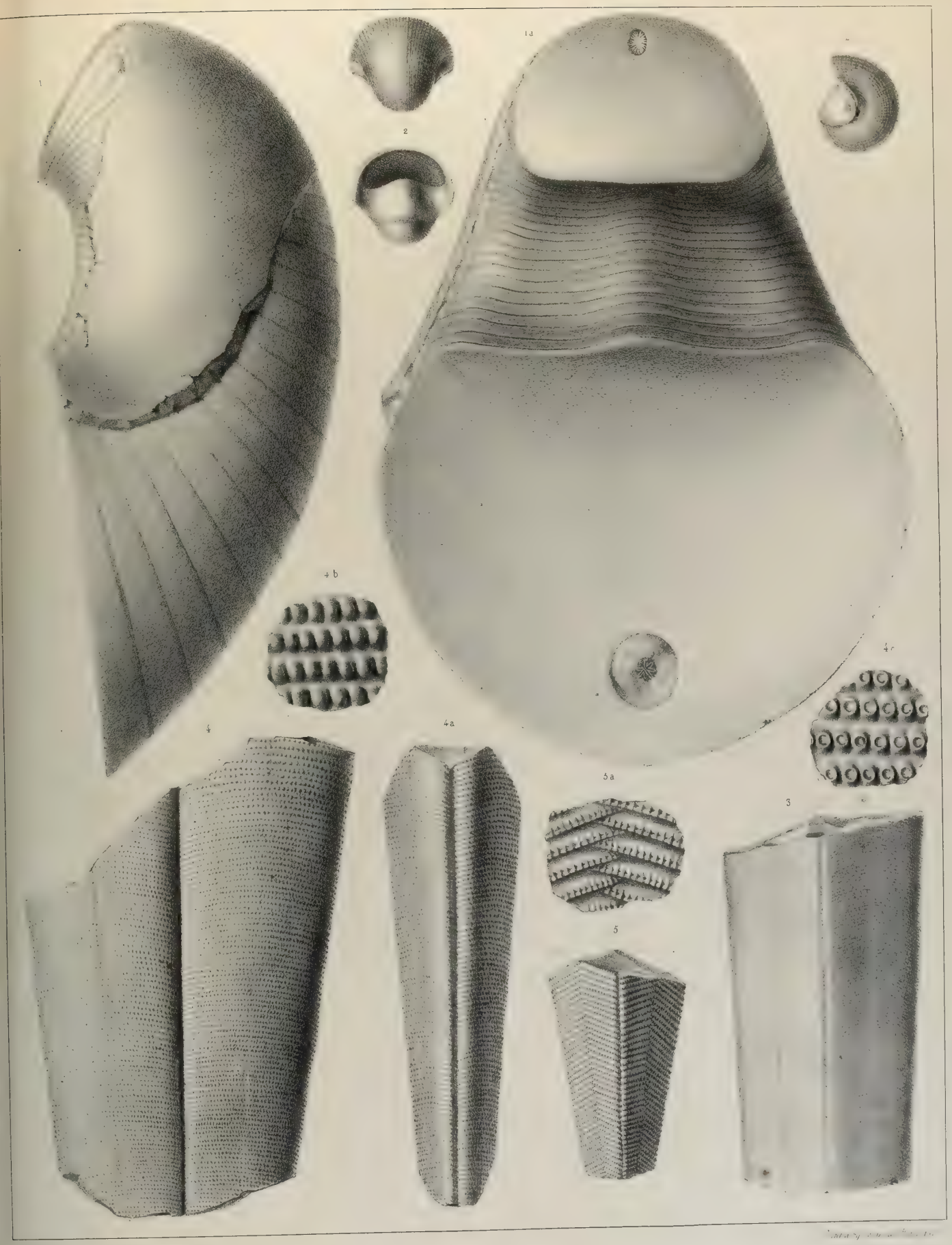
[illegible]

Thiolat del

Fig 1 1a Orthoceratites Dannenbergii nob
2 2a ... subfusiformis de Munst
3 3a ... subpyriformis id.

Fig 4 4a 4b Cyrthoceratites lamellosus nob
5 5a 5b ... ornatus Gold
6 Belerophon striatus de Fer

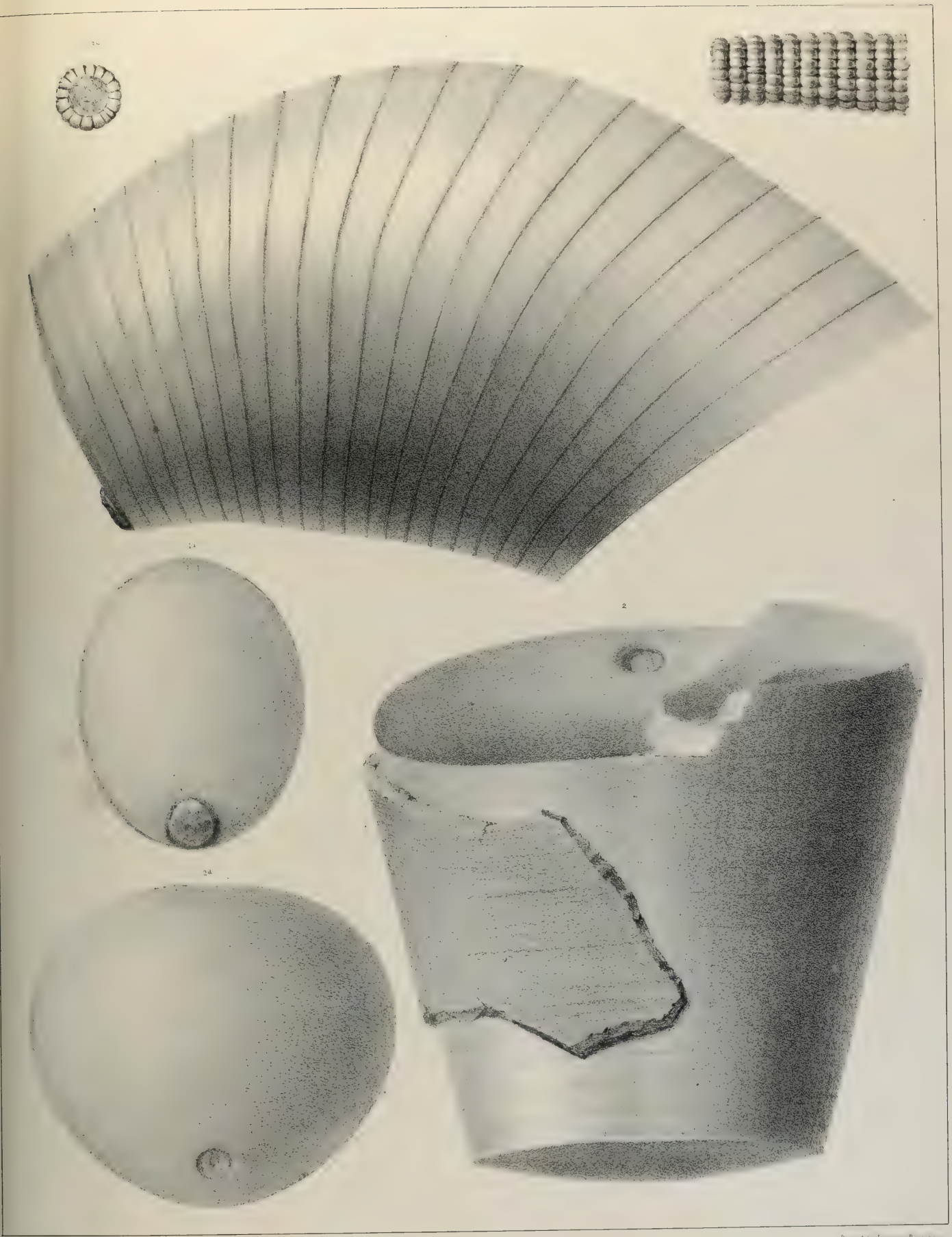
Fig 7 7a 7b Belerophon murchisoni d Orb
8 ... id var nob
9 tuberculatus d Orb



Thiolat del.

11ª Cyrthoceratites depressus Gold
22ª Belerophon elegans d'Orb
3 Conularia Gervillei nob (From Kemmenau)

Fig 1 1a 1b 1c Conularia Gervillei nob (From Nehou)
5 5ª Ornata nob



Thulat del.

Printed by Lemercier Benoit

Fig. 1 1a Phragmoceratites suoventricosus nob.
2 2a Cyrthoceratites lineatus Gold.
3 3a Syphon of orthoceratites.

Thiolat del.

Printed by Longman Brown et al.

Fig. 1 1a Goniatites costatus nob.
2 2a 2b Cyrthoceratites eifeliensis nob.
3 3a " tetragonus nob.
4 4a Orthoceratites [illegible]
5 5a Conularia [illegible]
6 6a 6b 6c [illegible]

Thiolat del.

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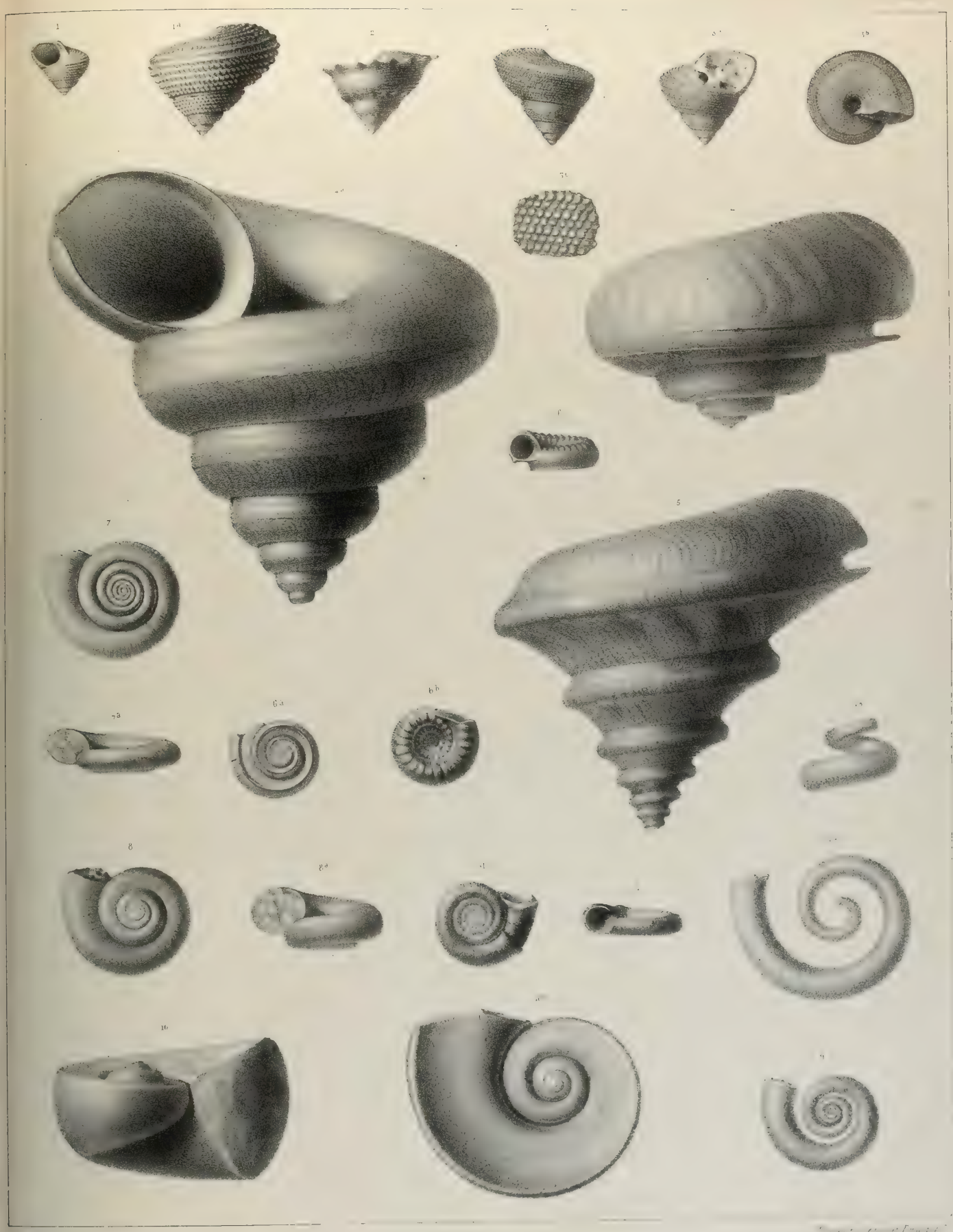
Fig 1	Buccinum	arculatum	Schlot.
2	.....	Schlotheimi	nob
3	Murchisonia	coronata	nob
4	.....	intermedia	nob
5	.....	id var a	
6	.....	angulata	Phil

Fig 8	Murchisonia	bilineata	nob
9	-	bigranulosa	nob
10		id var a	
11	..	a var b	
12	.. ..	binodosa	nob
13 13a	..	tricinita	var nob

Fig 15 15a	Monodonta	purpurea	nob
16	Trochus	Ivanii var	Let
17 17a	Pleurotomaria	catenulata	nob
18 18a		Orbiangana	nob
19 19a		id var a	
20 20a		id var b	
21 21a		Lonsdalei	nob



Thiolat del.

Fig. 1. Pleurotomaria Beaumonti nob
1a ..... id. (aucta.)
2. ..... lembata Phil var.
3. 3a. 3b. 3c. ..... elegans nob.
4. ..... delphinuloides Gold.

Fig 4a Pleurotomaria delphinuloides var
5 ..... exaltata nob
6. 6a 6b Euomphalus Labadyei nob.
7. 7a ..... planorbis nob

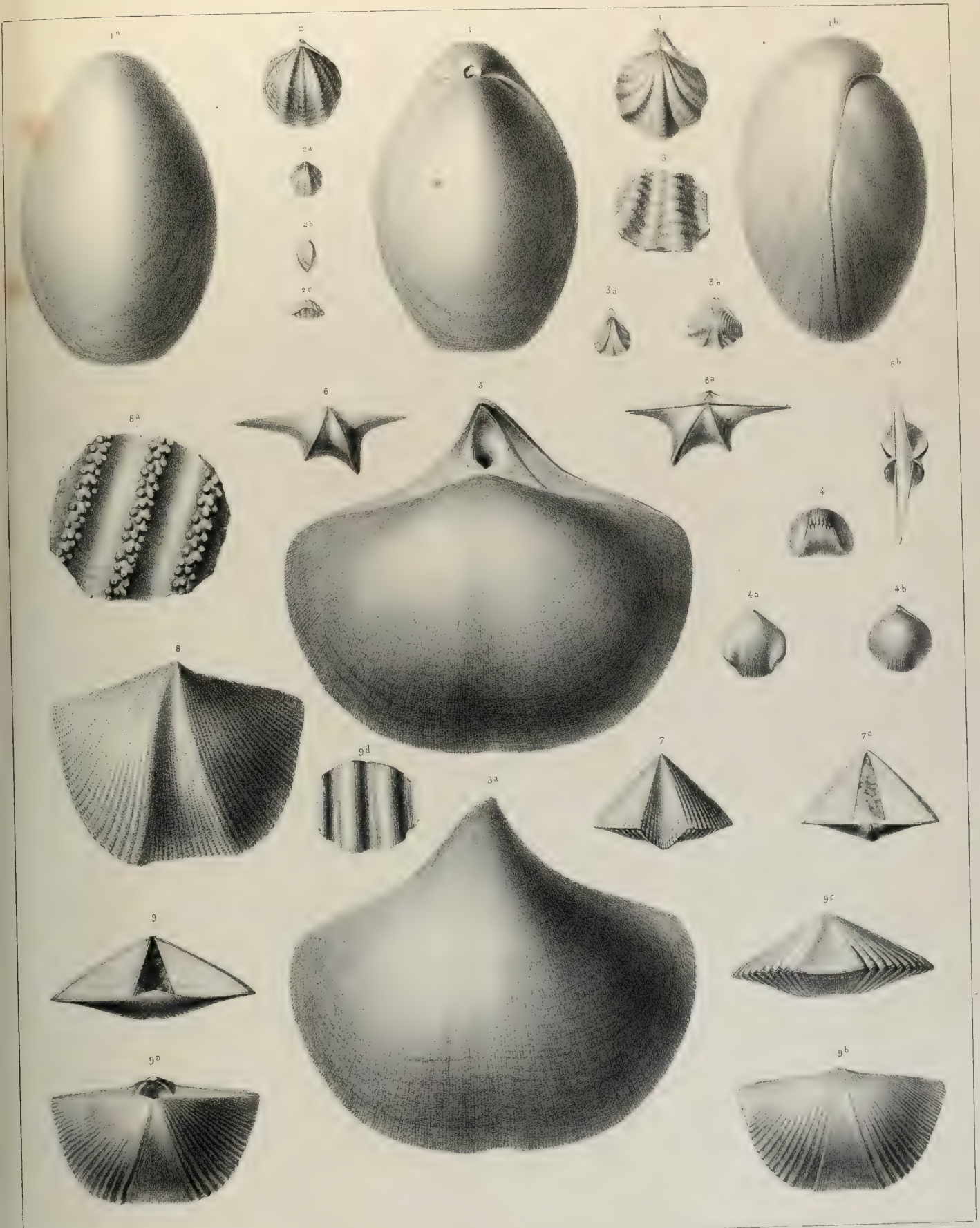
Fig 8. 8a [illegible]
9. 9a. 9b [illegible]
10. 10a [illegible]
11. 11a [illegible]

Thiolat del.

Fig 1. 1a Euomphalus Goldfussi nob
2. 2a id. (junior)
3 Schizostoma radiata nob
3a 3b id (cast)

Fig 4. 4a Natica margaritifera nob
5. 5a subcostata nob.
6 id. var
7. 7a 7b Euomphalus Schnuru nob.

Fig 8. 8a 8b Schizostoma [illegible]
9. 9a ... Cirrus. ... Leonhardi nob
10. 10a Pileomus [illegible]



Thiolat del.

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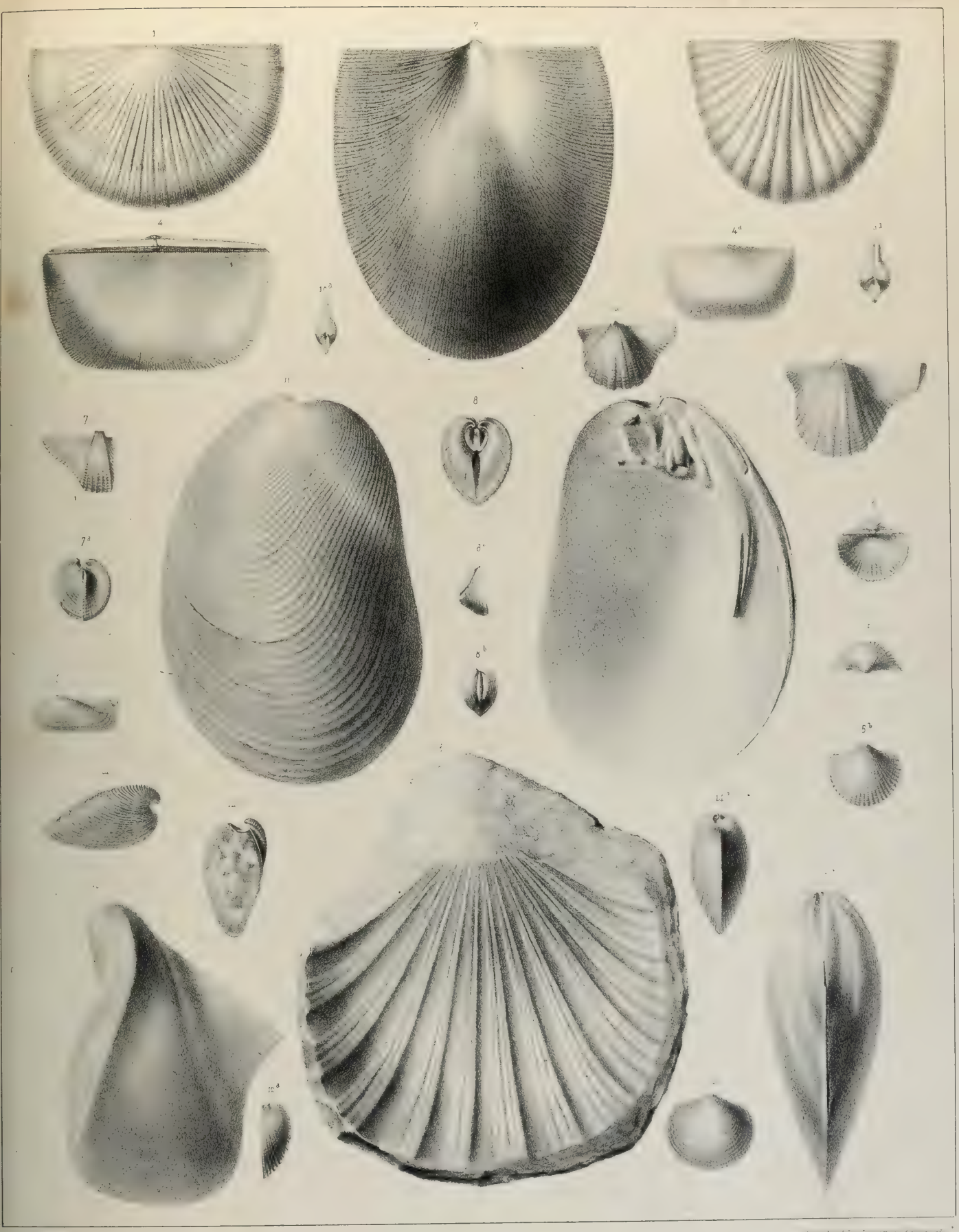
Fig. 1 1a 1b Terebratula carguae nob.
2 lepida Gold. (acta)
2a 2b 2c id. (magnit. naturali)
3 3a ferita de B. var. (aucta)

Fig. 3a Terebratula ferita var. b
3b id. var. typus with (?) spiræ
4 4a 4b [illegible] nob.
5 5a Strygocephalus dorsatus Gold.

Fig. 6 6a 6b Spirifer [illegible] nob.
7 7a aperturatus Schlot. var. [illegible]
8 8a id. var. [illegible]
9 9a 9b 9c mediotextus nob.

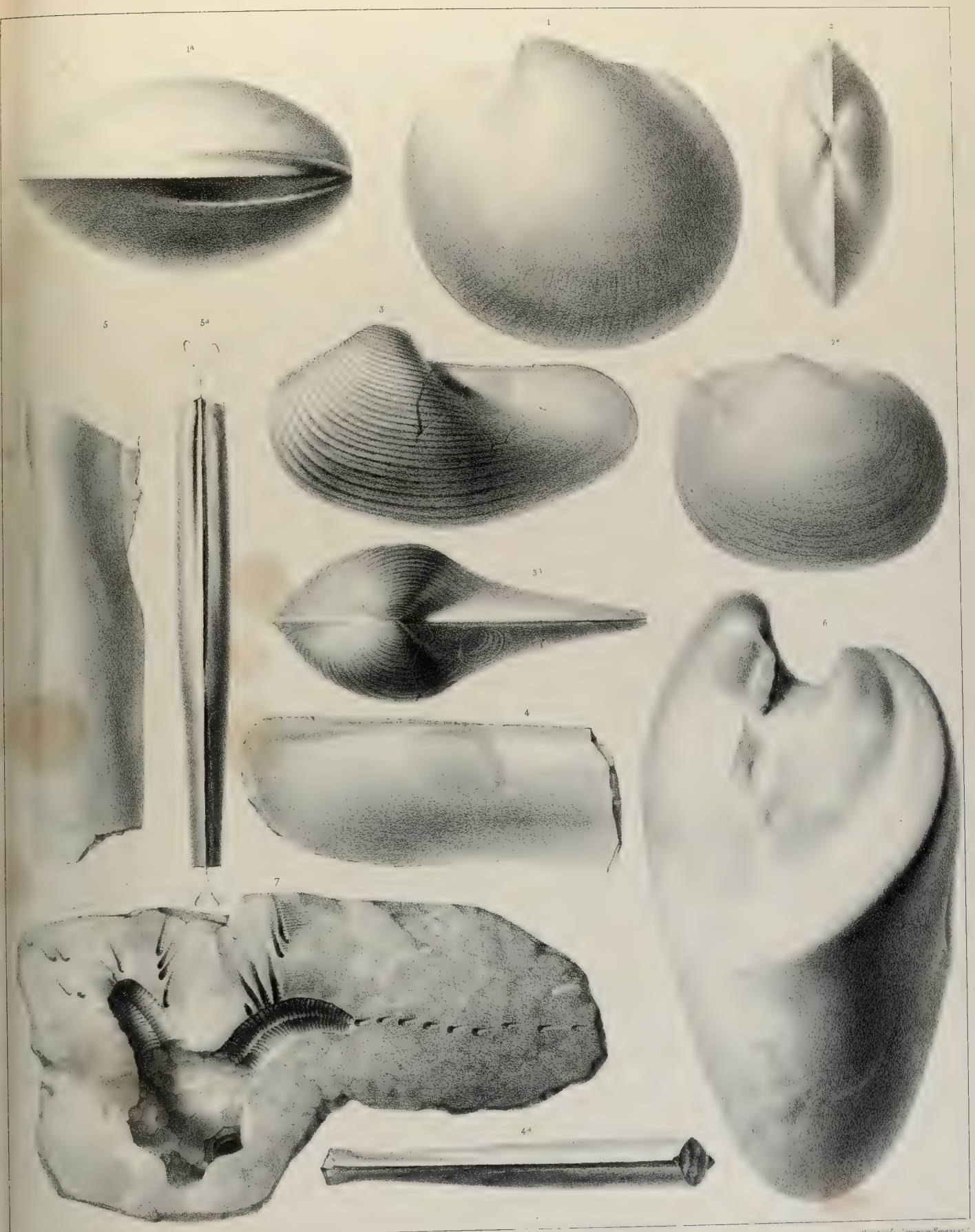


Thiolat del.

Fig. 1 Orthis Sedgwicki nob.
2 —— Murchisoni nob.
3 —— Subarachnoides nob.
4, 4a —— lépis nob.
5, 5a 5b minuta Gold.

Fig. 6 Arca Michelini nob.
7, 7a Cardium auxiformis nob.
8, 8a 8b —— Lyellii nob.
9, 9a —— vilmarense nob.
10, 10a —— id. var.

Fig. 11, 11a [illegible]
12, 12a [illegible]
13 Pecten [illegible]
14, 14a, 14b [illegible]
15, 15a Avicula [illegible]

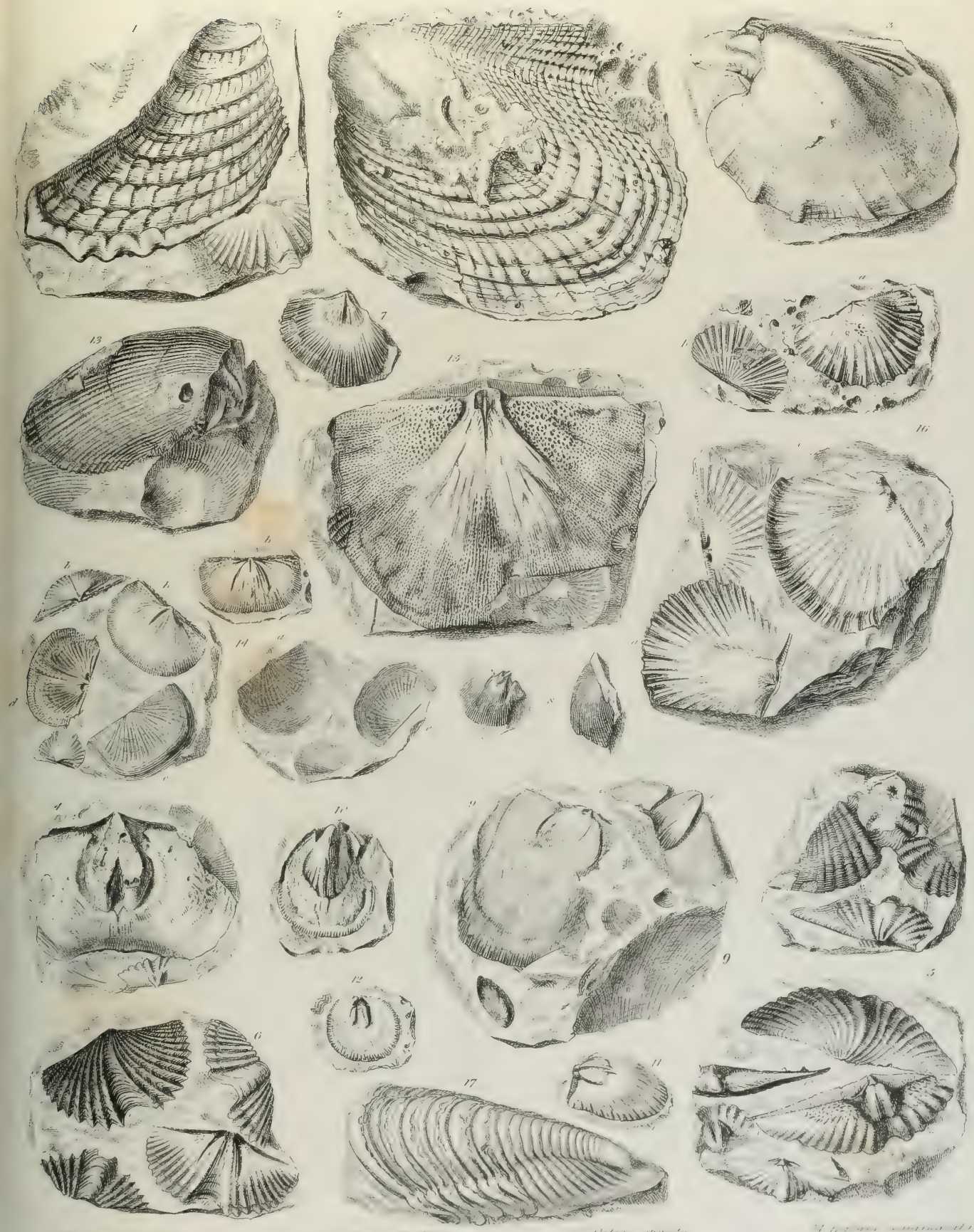


Thiolot del

Printed by Lemercier Benard et Cie

Fig 1 1a Lucina proavia Gold
2 2a Dufrenoyi nob
3 3a Pholadomya Mansteri nob

Fig 4 4a Sowa Eastheidi nob
5 5a pelagicus Gold
6. Trigonia? sulcata Gold.
7 Aenocrinus typus Bronn



1 & 2. Pterinea lamellosa
3. P. costata
4. Atrypa curvata
5. Spirifer speciosus
6. Spirifer microptera
7. Orthis striatosa
8. O. virgulata
9. O. Pecten
10. Orthis [illegible]
11. O. partita
12. O. [illegible]
13. Leptæna profunda.
14. Leptæna [illegible]
15. [illegible]
16. [illegible]
17. Homalonotus Knightii

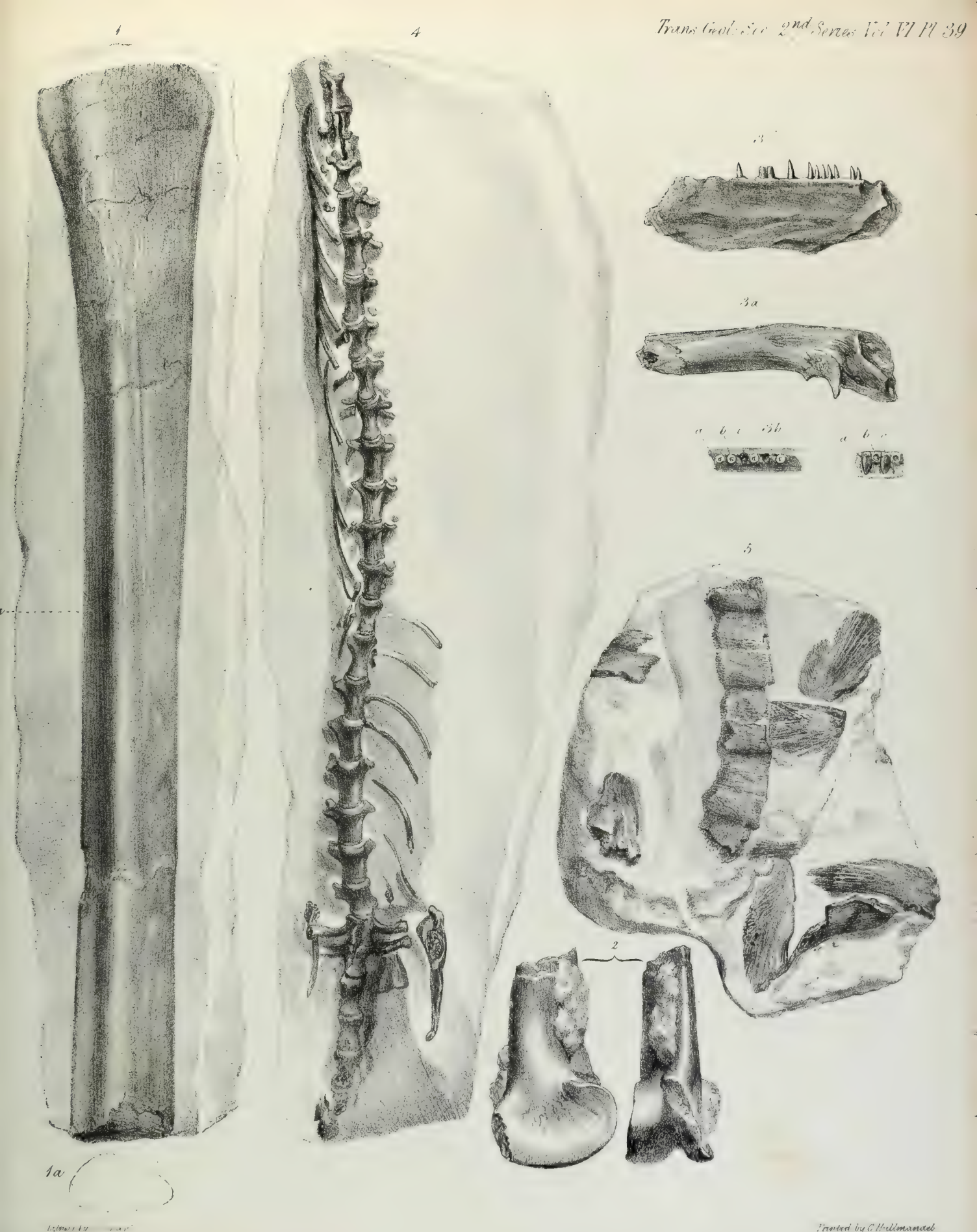


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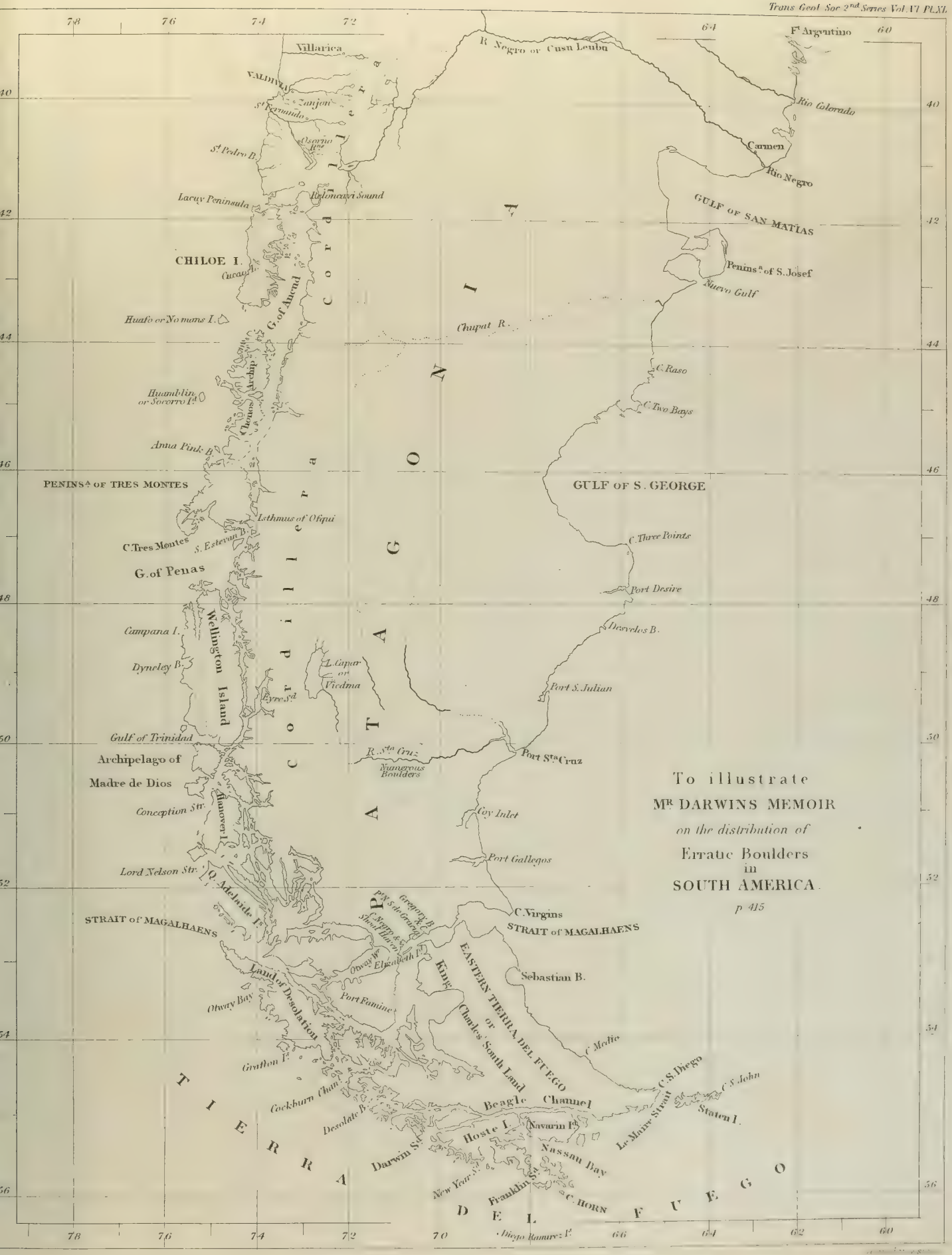
Fig 1 & 2 Ornitholites 3 3a 3b 3c & 4 Raphiosaurus 5 Chelone
From the Chalk of Kent

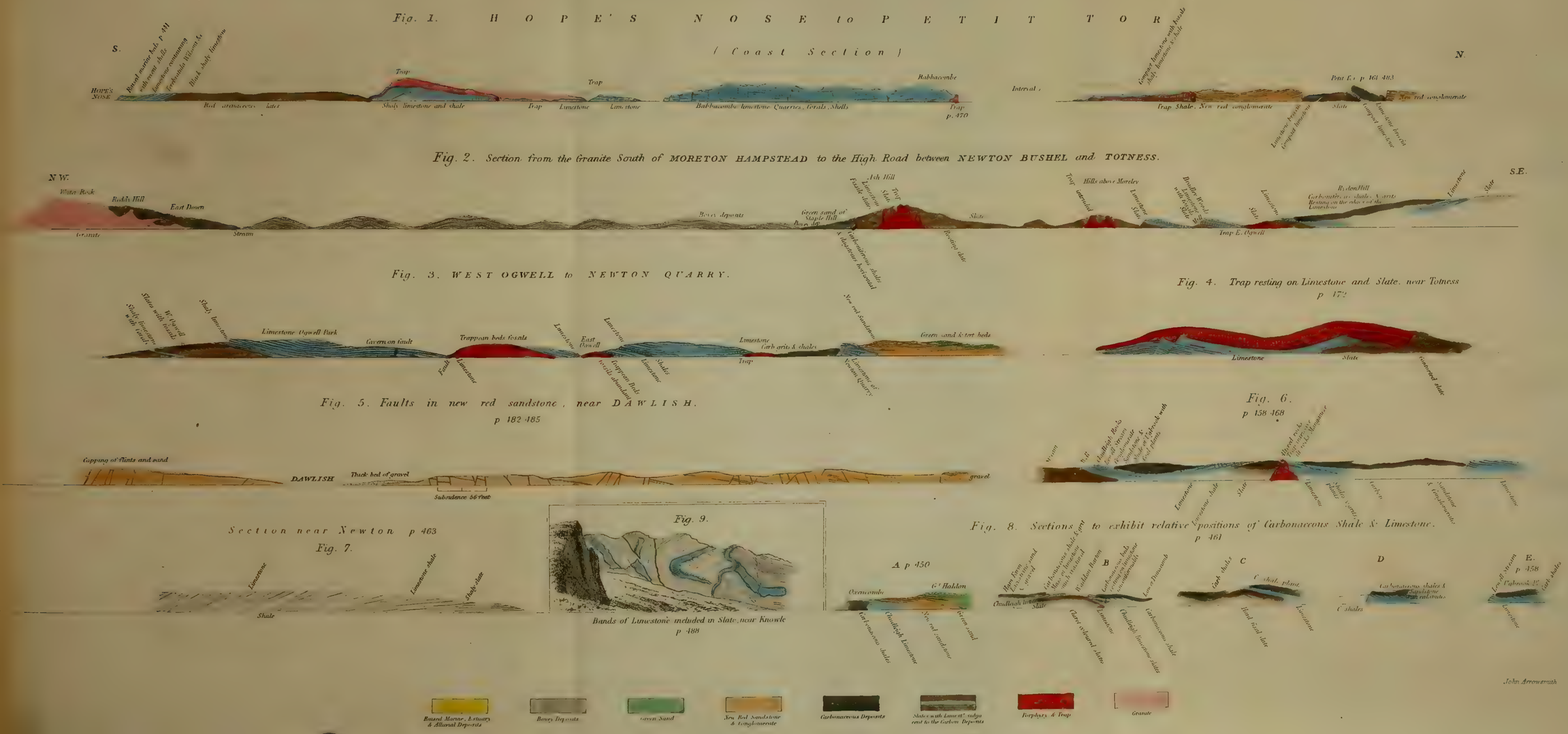

To illustrate
Mr. DARWINS MEMOIR
on the distribution of
Erratic Boulders
in
SOUTH AMERICA.
p. 415
Villarica
VALDIVIA
Zanjon
St. Fernando
Osorno Rd.
St. Pedro B.
Lacuy Peninsula
Reloncavi Sound
CHILOE I.
Cucao B.
G. of Ancud
Huafo or No mans I.
Huamblin or Socorro Pt.
Chonos Archip.
Anna Pind. B.
PENINSA. OF TRES MONTES
Isthmus of Ofiqui
C. Tres Montes
S. Esteban B.
G. of Penas
Campana I.
Dynneley B.
Wellington Island
Eyre Sd.
L. Gapar or Viedma
Gulf of Trinidad
Archipelago of Madre de Dios
Conception Str.
Hanover I.
Lord Nelson Str.
Q. Adelaide I.
STRAIT of MAGALHAENS
Land of Desolation
Otway Bay
Grafton Pt.
Cockburn Chan.
Desolate Pt.
Otway Wr.
Elizabeth Pt.
Port Famine
Gregory B.
Pt. St. Gregory
Negro & Shoal Haven Rs.
Kings
Charles' South Land
EASTERN TIERRA DEL FUEGO
Sebastian B.
C. Malie
C. S. Diego
C. S. John
Staten I.
Le Maire Strait
Beagle Channel
Hoste I.
Navarin Pt.
Nassau Bay
Darwin Sd.
New Year Sd.
Franklin Sd.
C. HORN
Diego Ramirez I.
TIERRA DEL FUEGO
R. Negro or Cusu Leubu
Ft. Argentino
Rio Colorado
Carmen
Rio Negro
GULF OF SAN MATIAS
Penins. of S. Josef
Nuevo Gulf
Chupat R.
C. Raso
C. Two Bays
GULF OF S. GEORGE
C. Three Points
Port Desire
Desvelos B.
Port S. Julian
R. Sta. Cruz
Numerous Boulders
Port Sta. Cruz
Coy Inlet
Port Gallegos
C. Virgins
STRAIT of MAGALHAENS
PATAGONIA
Cordillera
78
76
74
72
70
66
64
62
60
40
42
44
46
48
50
52
54
56

SOUTH EAST OF DEVONSHIRE.

TO ILLUSTRATE Mr AUSTENS MEMOIR

Scale 2 Miles equal to One Inch

SECTIONS TO ILLUSTRATE Mr. AUSTEN'S MEMOIR ON PART OF THE SOUTH EAST OF DEVONSHIRE.



John Arrowsmith

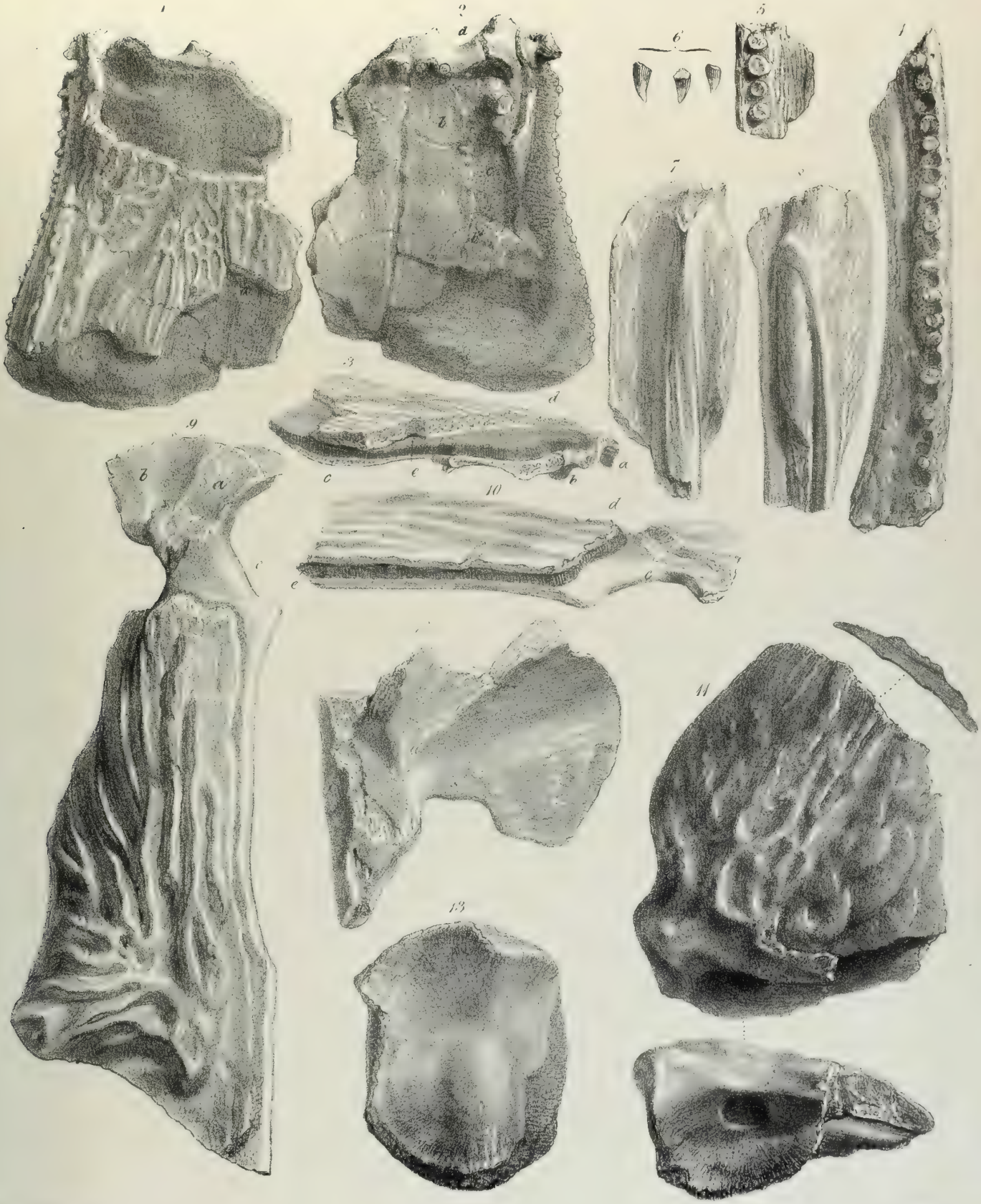


Fig 1.2.3 Labyrinthodon leptognathus. Fig. 4 11. Labyrinthodon pachygnathus

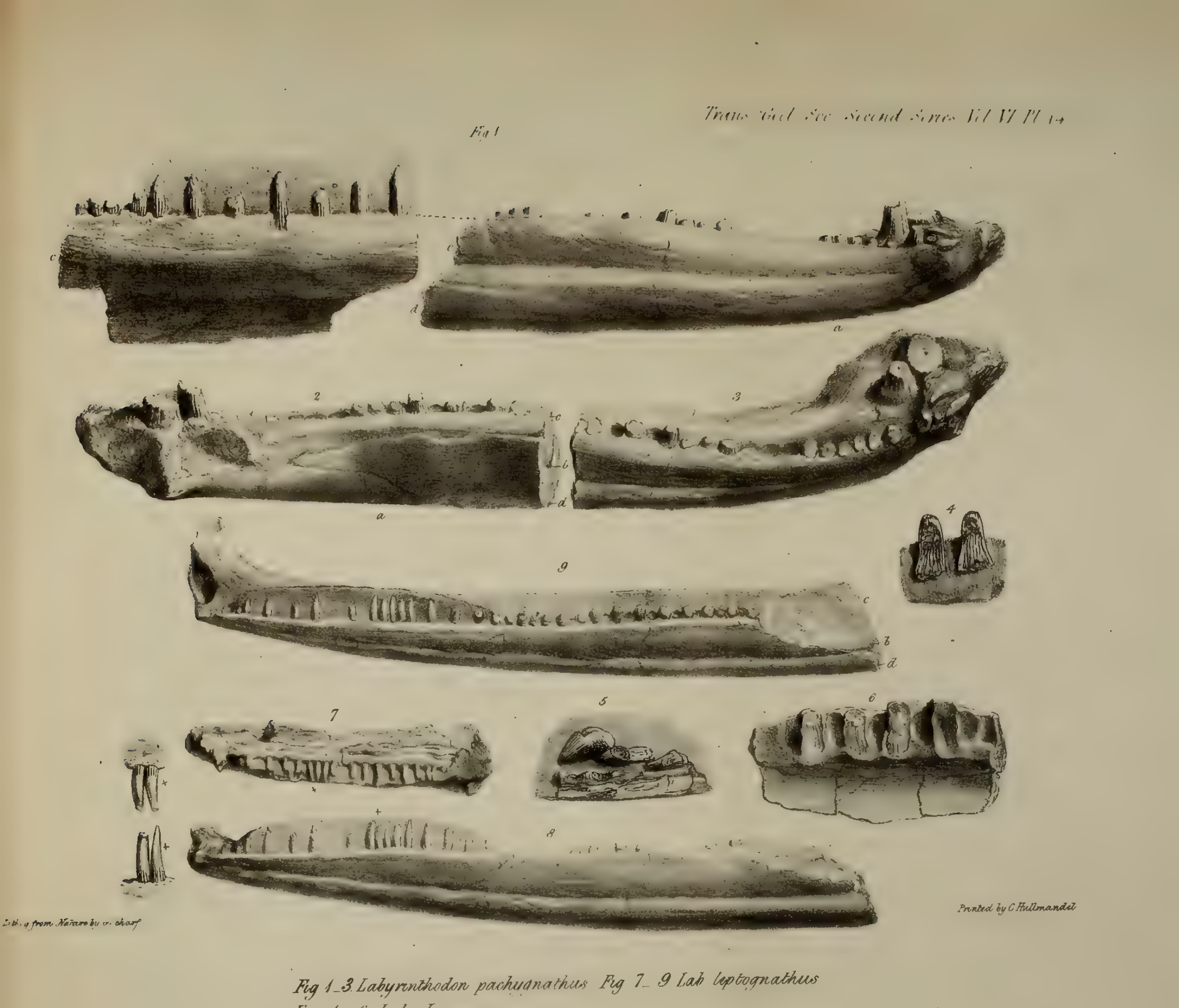


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Fig 1_3 Labyrinthodon pachygnathus Fig 7_9 Lab leptognathus
Fig 4 6 Lab Juegeri

...thog from Nature by G. Scharf

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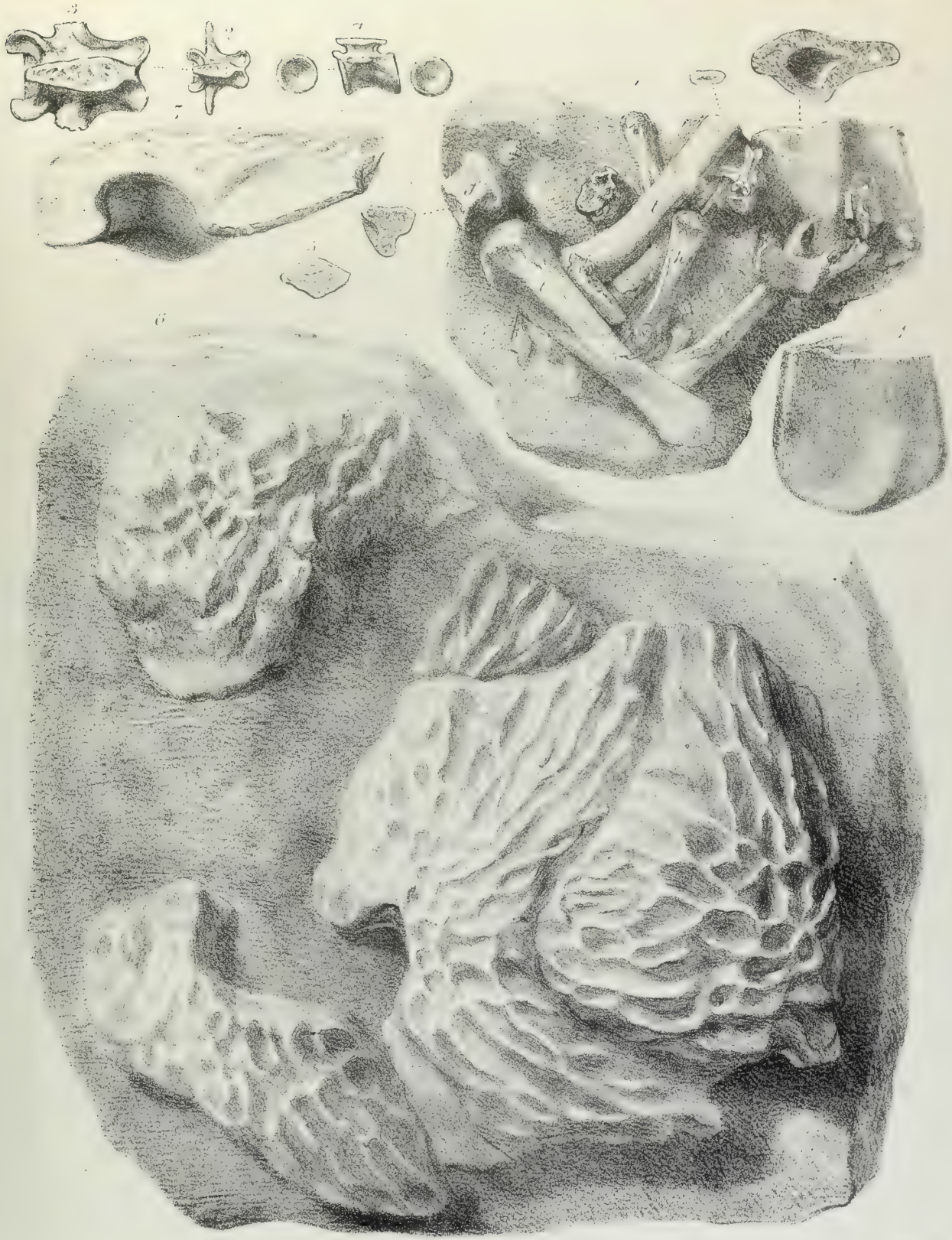
Fig. 1_4, 11_18 Labyrinthodon pachygnathus. 5_8 Lab. leptognathus.

Fig. 9, 10 Lab. ... Fig. 19 Coprolite



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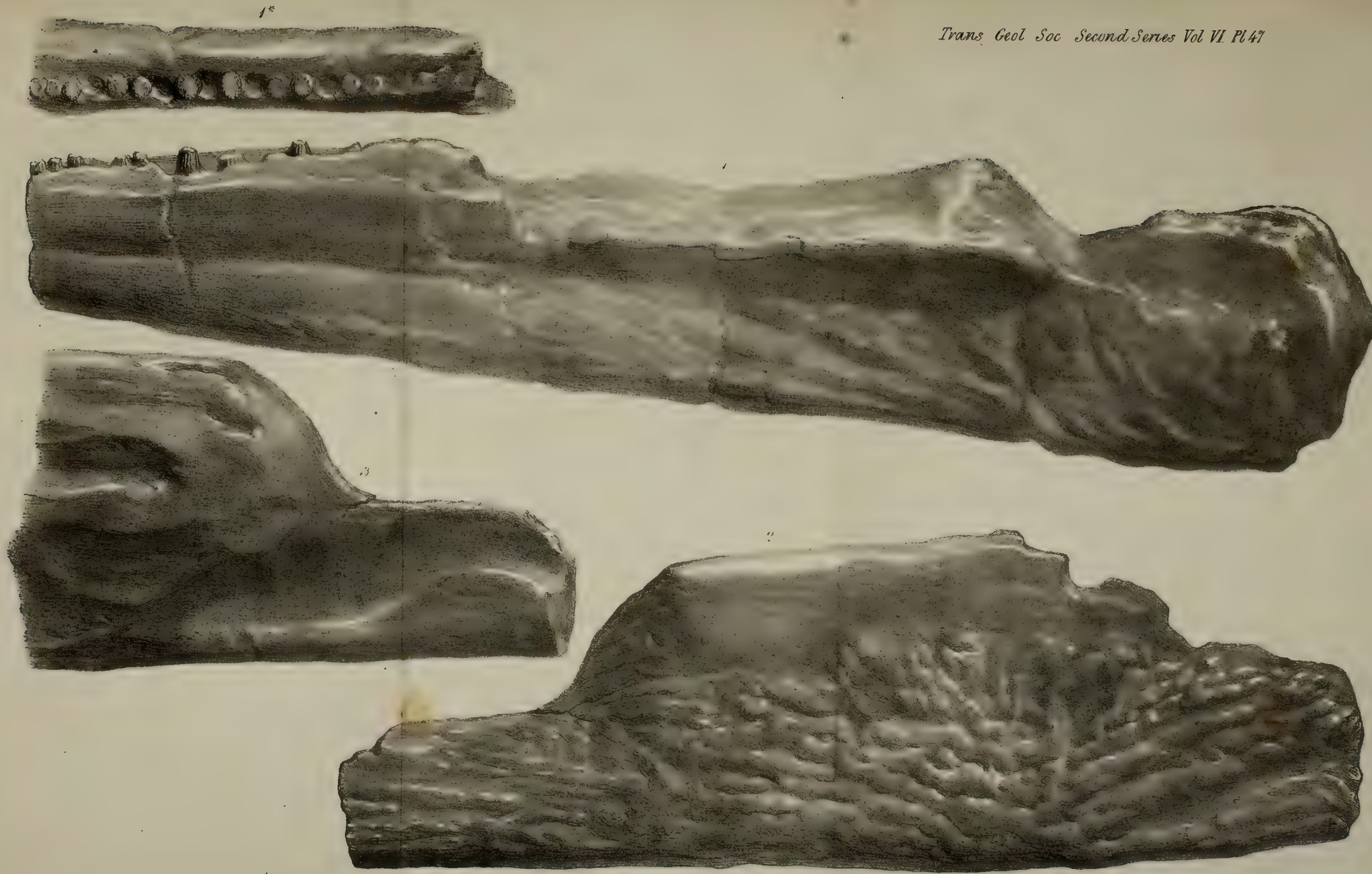
1 5. Labyrinthodon scutulatus 6 7. Labyrinthodon pachygnathus



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Labyrinthodon Jaegeri.

SECTIONS OF CUTTINGS ON THE BIRMINGHAM AND C

Lower New Red — New Red Sandst & Conglom — Red Saliferous Marl — Keuper Sandstone — Grey

Modern Alluvium

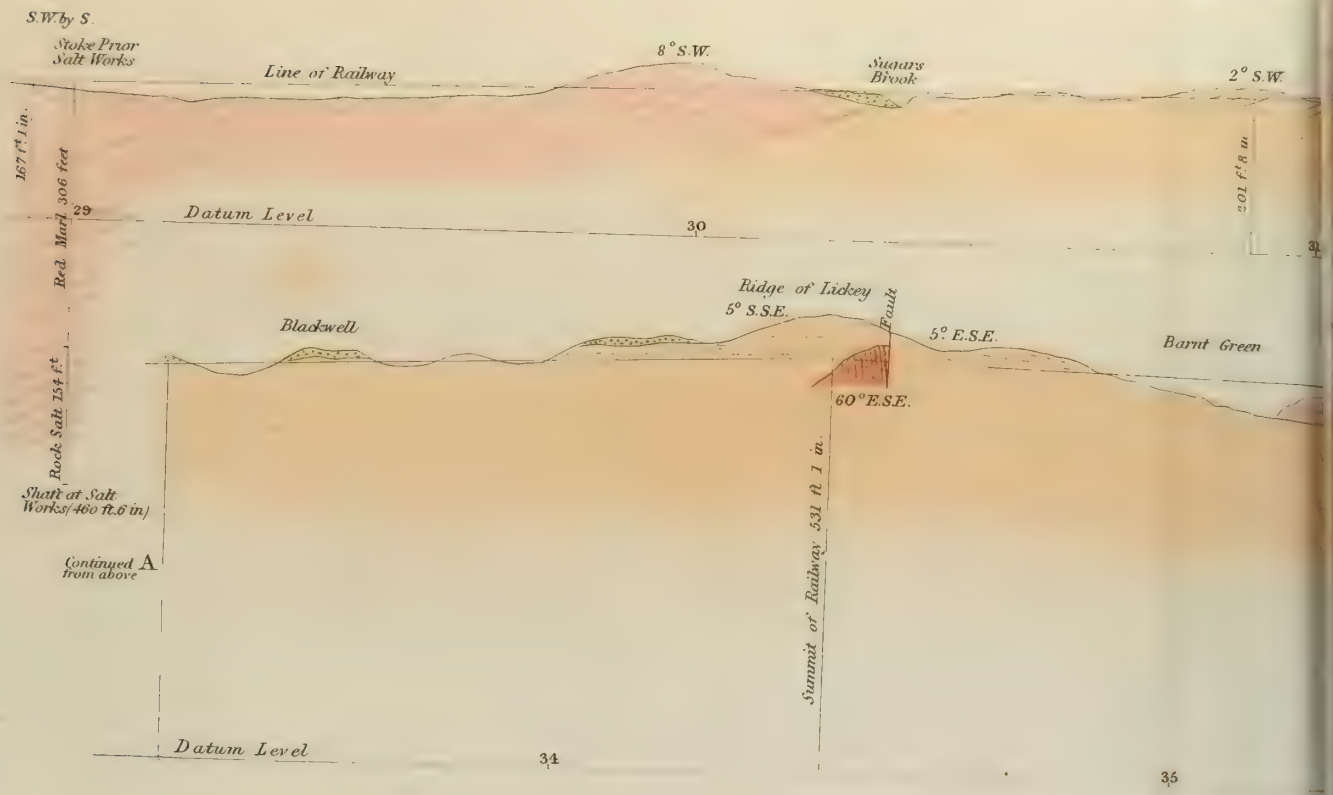
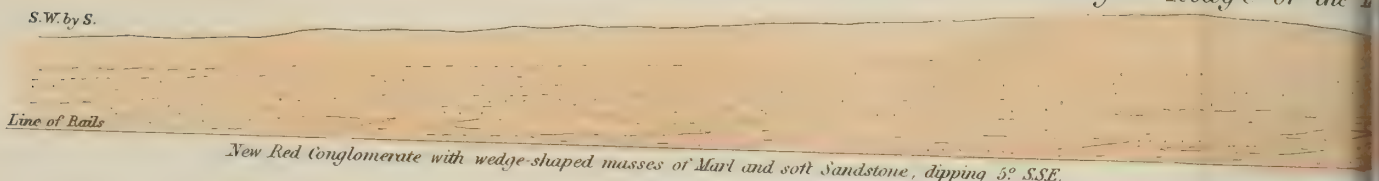
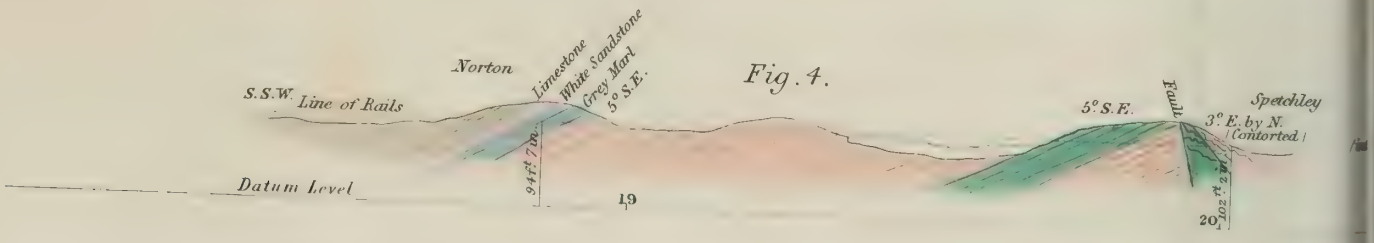


Fig 2. Ridge of the L



New Red Conglomerate with wedge-shaped masses of Marl and soft Sandstone, dipping 5° S.S.E.



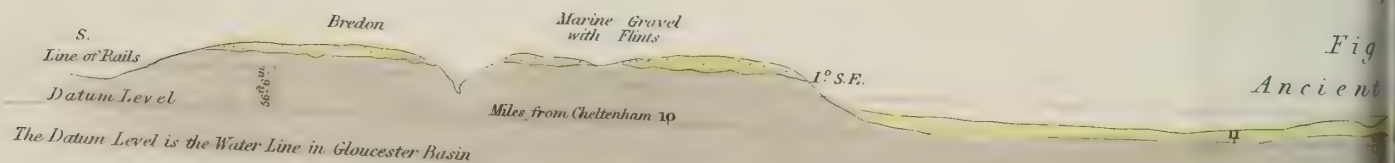


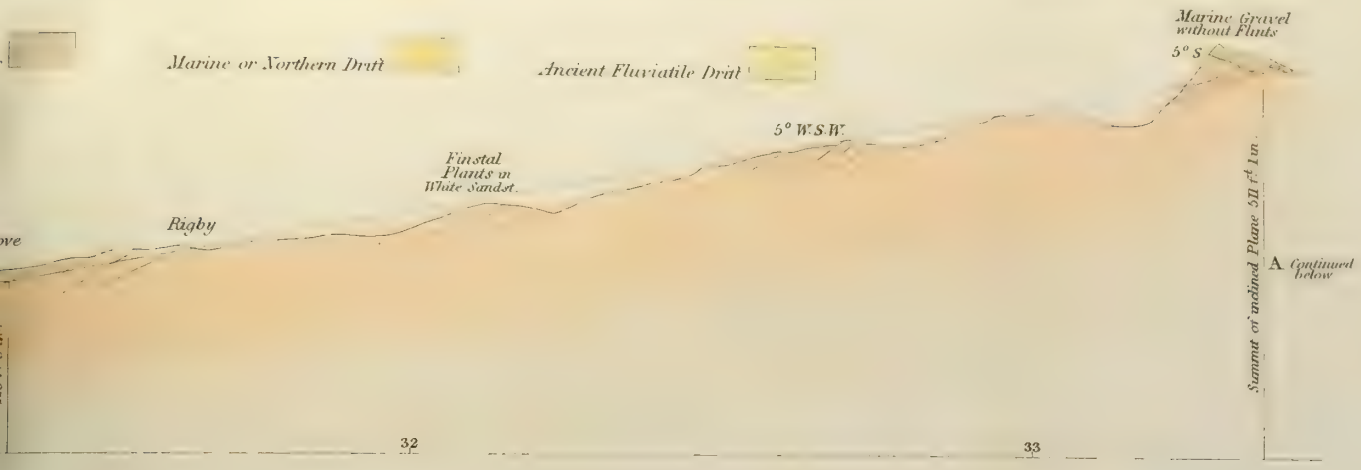
Fig
Ancient

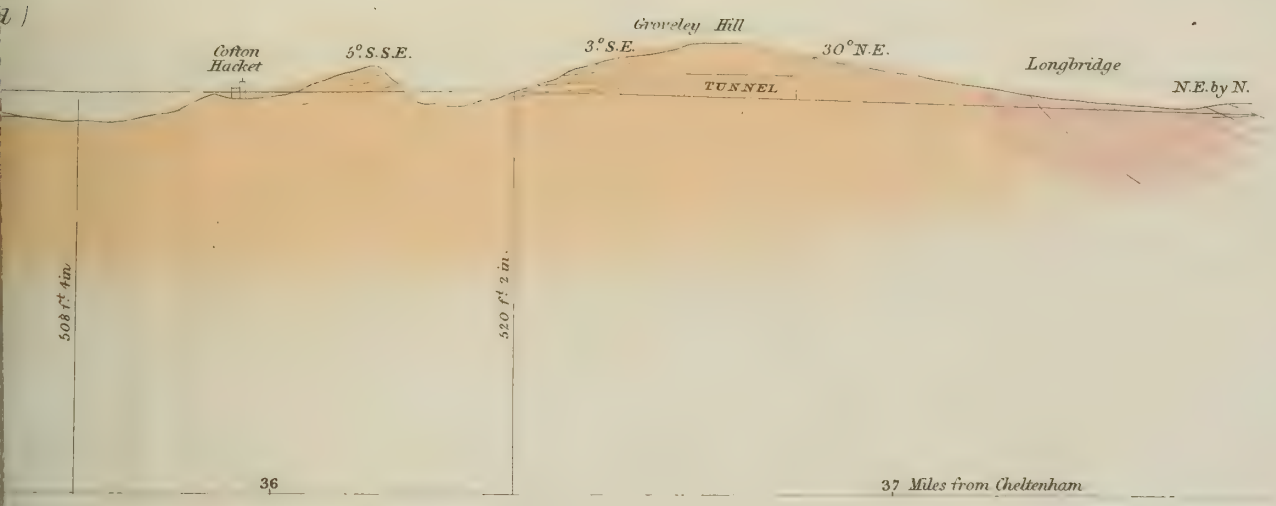
The Datum Level is the Water Line in Gloucester Basin

H F. Strickland del!

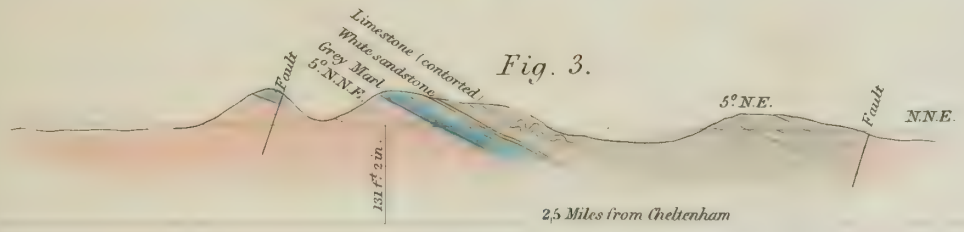
Figs 1, 3, 4, & 5 are d

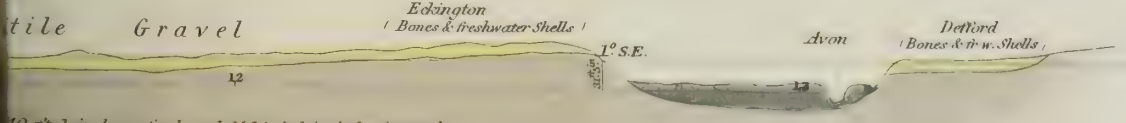
RAILWAY TO ILLUSTRATE Mr STRICKLAND'S MEMOIR





form Scale of 80 feet = 1 inch /





10 ft-1 inch vertical, and 1584 ft-1 inch, horizontal.

John Arrowsmith

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